Sponsors

Ministry of Non-conventional Energy Sources, Government of India

Indian Renewable Energy Development Agency Limited, Government of India

UNESCO, New Delhi

REPSO India (Winrock International)

All India Council for Technical Education

Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development

International Centre for Theoretical Physics

Shell India Private Limited

Asia and Pacific Centre for Transfer of Technology

Renewable energy education

current scenario and future projections

Renewable energy education
current scenario and future projections

(Proceedings of the Sixth International Symposium on
Renewable Energy Education held on
26–28 November 1998 in New Delhi, India)

Edited by
Anil Misra

Organized by

Tata Energy Research Institute

Solar Energy Society of India

In association with

International Association for Solar Energy Education

© Tata Energy Research Institute 1999

ISBN 81-85419-58-2

All rights reserved. No part of this publication may be reproduced in any form or by any means without prior permission of the Tata Energy Research Institute.

Published by
teri
Tata Energy Research Institute
Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi - 110 003, India
Telephone +91 11 460 1550, 462 2246
Fax +91 11 462 1770, 463 2609
E-mail mailbox@teri.res.in
Web www.teriin.org

Printed by
Multiplexus (India)
94, B D Estate, Timarpur
Delhi - 110 054, India

Contents

ix **Preface**

xi **Acknowledgements**

xiii **Foreword**

xv **Report of the Organizing Secretary**

1 **Special session of invited lectures**
3 Session summary
5 Ten years with the International Association for Solar Energy Education
Lars Broman
11 Global renewable energy education and training: World Solar Programme 1996–2005
Boris Berkovski
24 Trends and issues in renewable energy education
H P Garg

31 **Session I: Renewable energy education policy/Curriculum design/Case studies**
33 Session summary
35 Renewable energy in university physics teaching
Arne Auen Grimnes
42 Creating a European Solar Engineering School
Lars Broman
48 Design and teaching of a course on renewable energy at Birla Institute of Technology and Science, Pilani
M Ramachandran
58 Designing packages for renewable energy education
Anitha Saravanan
69 Present status and future direction of renewable energy education in Bangladesh
M A R Akhanda
74 Impact-oriented comprehensive approach for energy education
Jyotirmay Mathur
80 Teaching of wind energy at advanced undergraduate and postgraduate levels
Kunal Ghosh
88 Renewable energy training for desert development
Salah Arafa

103 **Session II: Vocationalization of renewable energy education/Training and awareness programmes**
105 Session summary
108 Training programme on solar energy utilization
R Saravanan
113 Syllabus design of rural technology course for technician diploma in mechanical engineering in Nepal
Riddhi Ratna Sthapit
120 Energy education and capacity building of NGOs: TERI's experience
Shirish Sinha
133 Teaching and training communities of Kathmandu Valley in the use of solar parabolic cookers
Sama Shrestha
144 Renewable energy education and training for integrated rural development
Subodh Kumar
154 Teaching peasants how to build more energy-efficient houses
Jorge Mitchell

165 **Session III: Miscellaneous topics**
167 Session summary
169 Physics with energy studies specialization: an experience
S K Samdarshi
182 Use of the Internet in renewable energy education
Joachim Göttsche
190 Training and education activities on solar buildings in India
Bibek Bandyopadhyay
199 Curriculum of a B. E. Civil Engineering course on renewable energy
Dulal Goldar
206 Human resource development for solar energy
Herbert A Wade
221 Role of renewable energy education in the development of arid regions
N M Nahar

227 **Session IV: Media and advanced electronic technologies in the promotion of renewable energy education**
229 Session summary
231 Electronic communication technologies for renewable energy education
Christopher Gronbeck
246 Education television as a medium for renewable energy technology propagation
D Mutharasu
250 Teaching aids for lectures on renewable energy sources – an example from Slovenia
Saso Medved
262 Press as a development tool in publicizing renewable energy education and knowledge
S Ganesh

267 Concept and design of photovoltaic systems with PV-CODE: a dedicated computer program for teaching and research purposes
J C Vernetti dos Santos

279 **Session V: Renewable energy education in schools and colleges**
281 Session summary
283 India's leadership in renewable energy development for a sustainable future
B S K Naidu
299 Renewable energy education in school science curriculum in India
R D Shukla
307 Renewable energy education and research programme in postgraduate level curricula: a case study and analysis
Shahida Rafique
313 Solar water heating systems for training and demonstration in postgraduate programmes
R L Sawhney
333 SOLIS: Solar energy in schools
Karl Torstein Hetland
341 Solar energy competition
Einar Oterholm
345 Evaporative cooling of buildings in hot regions
S P Jain

351 **Index**

363 **Appendix 1: Programme**

369 **Appendix 2: List of authors**

371 **Appendix 3: List of participants**

379 **Appendix 4: List of participants from schools/colleges**

Preface

The Sixth International Symposium on Renewable Energy Education went beyond previous such events and provided an opportunity to a number of renewable energy experts, educationists, government officials, and non-governmental organizations to focus on course work in the field of renewable energy education both at the global and regional level. The symposium was held in conjunction with an exhibition on renewable energy systems, an exposition through multimedia packages, and video films on very specialized features and specific topics. A model/poster competition was also organized, creating a great deal of interest and awareness among college and school students and their teachers in particular. This symposium was a small but vital step in popularizing renewable energy education techniques and pedagogical tools and in the overall implementation of renewable energy programmes and policies at various levels nationally and globally.

It is very pleasing to note that the presentations during the symposium covered all the important aspects of renewable energy education that are necessary to make it effective, including topics such as the role of modern communication technologies in education and training.

The proceedings of the symposium represent high-quality material and the product of a dialogue, which will be pursued with greater vigour and interest in similar such exercises in future. Indeed, the cause of sustainable development and greater use of renewable energy technologies rests essentially on proper public awareness and greater knowledge on the part of those who are to implement programmes of education in this field. As we enter the new millennium, the issues and approaches identified in the symposium would add greater relevance to actions that have to be taken towards the use of all forms of resources in a sustainable manner. Renewable energy resources would be at the core of such strategies.

R K Pachauri
Director, TERI

Acknowledgements

I gratefully acknowledge the support offered by all the persons who enabled the completion and publication of this book containing the proceedings of ISREE-6 in a very short time.

My special thanks to the several authors who submitted their manuscripts in time and responded quickly to our queries. The Publications Unit at TERI has been responsible for the production and publication of this book. My thanks to the colleagues in the Publications Unit – Ms Mudita Chauhan for editorial assistance and managing the publication of the proceedings; Mr K P Eashwar, Ms C V Indira, Ms Meena S Janardhan, Ms Jaishree Ram Mohan, and Ms Anitha Saravanan for assistance in copy-editing; Mr Yateendra Joshi for design and layout; Mr R Ajith Kumar for typesetting; Mr R K Joshi for the artworks; and Mr T Radhakrishnan for supervising the production. Mr Atul Dhyani and Mr I I Jose painstakingly provided the much-needed secretarial assistance. Thanks are also due to the colleagues at Library and Information Centre for indexing the volume.

My heartfelt thanks are also due to the sponsors who provided the necessary funds for this book.

I would like to express my gratitude to Prof. S C Bhattacharya, President, International Association for Solar Energy Education for writing the foreword, and to Dr R K Pachauri for his indispensable guidance and for providing the preface to this book.

President,
IASEE

Convener,
ISES Committee
on Education

S C Bhattacharya

Foreword

Renewable energy education: current scenario and future projections
pp. xiii

At present, coal, oil, and natural gas account for about 77% of the global primary energy consumption. It is universally acknowledged that this pattern of energy consumption is not sustainable and that alternative sources of energy need to be developed to meet the rising world energy demand.

Increased utilization of renewable energy sources is regarded as a key element of any sustainable energy strategy. In some of the sustainable energy scenarios developed by international organizations, renewable energy accounts for about half of the total primary energy supplies by the middle of the next century. However, these scenarios can only be realized if appropriate public policies are implemented for vigorously promoting renewable energy. In particular, educational programmes to produce the technical manpower needed to facilitate the anticipated growth in the renewable energy industry as well as associated research, development, and demonstration activities need to be initiated/strengthened now.

The ongoing process of COP (Conference of Parties) to the United Nations Framework Convention on Climate Change appears to offer an ideal opportunity for promoting renewable energy technologies, particularly in developing countries, through the CDM (clean development mechanism) proposed in the COP-3 held in Kyoto, Japan in December 1997. Renewable energy education has become particularly important and urgent in view of these developments.

TERI, in association with SESI (Solar Energy Society of India) organized ISREE-6 (Sixth International Symposium on Renewable Education) during 26–28 November 1998. While the previous five symposiums were organized under the umbrella of IASEE (International Association for Solar Energy Education), the sixth symposium was organized as the first joint event of IASEE and the ISES (International Solar Energy Society) Committee on Education. It is planned that future symposiums will be similarly organized as joint events of these two bodies.

ISREE-6 was attended by more than 200 participants from 15 different countries and was probably the most successful symposium of the series so far. IASEE and the ISES Committee on Education are very pleased to have initiated this symposium organized by TERI and SESI.

TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi - 110 003
India

Anil Misra

Report of the Organizing Secretary

Renewable energy education: current scenario and future projections
pp. xv–xxiii

TERI, in association with SESI (Solar Energy Society of India) organized ISREE-6 (Sixth International Symposium on Renewable Energy Education) from 26–28 November 1998 at the Habitat Place, Lodhi Road, New Delhi. These international symposiums on REE (renewable energy education) are regular joint events of the IASEE (International Association for Solar Energy Education) and the ISES (International Solar Energy Society) committee on education.

Earlier symposiums were held in Borlänge, Sweden (1991); Oldenburg, Germany (1992); Borlänge, Sweden (1993); Bangkok, Thailand (1994); and Oldenburg, Germany (1996). The next symposium – ISREE-2000 – is scheduled to be held in Oslo, Norway in the year 2000.

ISREE-6 was a meeting ground for leading RE (renewable energy) experts/educators/teachers and government officials/advisers involved in educational policy making, from across the globe. The symposium provided a forum for deliberations on various aspects of REE at all levels, and for discussions on the preparation of teaching–learning resource materials in the area of RE.

Realizing the need to pay special attention to creating awareness about the potential and use of RETs (renewable energy technologies) at college and school levels, the organizers decided to simultaneously host a workshop for students and teachers. ISREE-6 also featured an exhibition of RE products, experiments for students on RE systems and devices, and a model/poster competition (*see Annexure 1 for the a list of award winners*) besides specialized lectures for students. TERI presented a set of 3 booklets – *Chhutki's Wonderful Adventures* (environmental play series) – to each participating student, and a book, *Mahatma Gandhi – an apostle of applied human ecology* – by Padma Bhushan awardee Dr T N Khoshoo to each participating teacher.

Stations were set up for schoolchildren and professionals to view videos and interact with internationally available multimedia packages on energy conservation and RETs. The range included programs for professionals engaged in designing photovoltaic systems (SolarSizer, available on CD-ROM, which helps in sizing photovoltaic systems to an optimal configuration) to those for children, captivating them with stories on energy conservation and helping them explore the immense possibilities of the use of RE.

Not many primary and secondary school students in India are aware of RETs, but as the feedback from youg participants at ISREE-6 shows, the situation can improve with proper education. Once students are involved in designing and developing RETs from a basic level, their interest is likely to grow.

Teachers and scientists from various countries discussed their experiences in this field – one excellent example came from Norway. The Agricultural University of Norway has established a programme where students design, build, and operate a demonstration site on RE each year. Allowing students to work in cooperation with scientists introduces them to the development of RE equipment for industrialization. As A Grimnes and P Heyerdahl, the university faculty members involved in the project pointed out, the project encourages students to have fun while they learn (*see Box 1*).

More than 200 delegates drawn from 15 countries participated in these events. These included Prof. David Mills, President, ISES; Prof. Yogi D Goswami, Vice President, IASEE; Mr Christopher Gronbeck, Director, Software Development, CREST (Centre for Renewable Energy and Sustainable Technology), USA, and several other distinguished professionals. Students and teachers from 30 Indian colleges and schools were seen to be the most enthusiastic participants.

In addition to the addresses by the invited guests during the inaugural session and invited lectures in a special session, 33 papers were presented in the following sessions:

1. REE policy/Curriculum design/Case studies (two sessions)
2. Vocationalization of REE/Training and awareness programmes
3. Media and advanced electronic technologies in the promotion of REE
4. REE in schools and colleges (two sessions)
5. Miscellaneous topics

The manuscripts of 4 presentations were not available to the organizers. However, 6 papers which could not be presented during ISREE-6 have been included at the requests of the authors who could not attend the symposium. In addition, an index of keywords, and lists of the participants and speakers are given at the end.

Box 1 Learning can be fun: the experiences of students, scientists, and industry in Norway

The Small-Scale Energy Technology Programme developed by the Agricultural University of Norway at Aas is a measure of the extent to which students can contribute to industrial development. The programme allows students to design, build, and operate RE devices and learn physics through practical applications.

Four projects have been taken up under the programme. In the first project, students completed the first stage of a Sunbike project. A motorbike with a built-in electrical motor was converted to use solar energy with photovoltaic panels, a charger, and an accumulator. In the second project, a graduate student designed and built a 1.5 kW vertical wind turbine. Another student compiled all relevant information on small-scale vertical wind turbines via the Internet and reference investigations. Conclusions from the report are being used to construct a larger wind turbine. In another project, first-level physics students developed and assembled a solar water heating system.

The fourth project depended on coordination between five students. A graduate student designed and built a biomass combustion system with a power output of 30–300 kW. The incinerator can use biofuels that are not pre-processed by grinding or chopping. Another student designed and built a turbine for producing electric power from the biomass heat. A third student designed and built a hot air engine. A fourth student designed a mathematical model of the incinerator to develop a control system. A fifth student designed a system for precise control of air supply for the incinerator. These activities generated enormous interest among other students, teachers, farmers, industry, and the press. Two of these students have been employed by Organic Power, a company created to industrialize the new solutions.

The need for rational allocation of resources for education and research in the field of RE was stressed at the inaugural session of ISREE. 'It is time for policy makers, educational and research institutions, and the industry to reach out beyond their narrow considerations and accept the niche for each source of energy,' said Dr A Ramachandran, President, SESI. Averring that RETs have come of age and deserve their rightful place in the budget, Dr Ramachandran said that a balanced allocation of resources between various classes of energy options was the need of the hour. 'We need all sources of energy and no single source will displace all the others,' he said.

Speaking on the occasion, Dr R K Pachauri, Director, TERI emphasized the use of advanced information technology for the promotion of RE use and education. Pointing out that the link between the producer and the consumer in the RE sector cannot be underrated, Dr Pachauri highlighted the importance of producing consumer-friendly goods. He underscored the need to spread awareness about RETs and to promote their cause in the field of education, a task that TERI has taken up.

Presiding over the inaugural session, Mr P R Dasgupta, Secretary, Ministry of Human Resource Development, Government of India, said that spreading awareness on conservation has to become a part of education. 'Men have become used to spending energy recklessly and have to be deconditioned,' he said. 'This is a Herculean task that teachers alone cannot manage; it needs the support of managers.'

Addressing the session, Prof. Y D Goswami, said that despite the fact that RETs are both technically feasible and reliable, people still find it hard to accept them as alternatives. The solution to this problem, he said, does not lie so much in R&D as in education and information dissemination.

Addressing delegates at the workshop, Prof. David Mills, President, ISES spoke on the role of the society in global promotion of RETs. The global solar programme planned by ISES includes a solar cities project; the setting up of integrated RE systems to make large island nations like Fiji less dependent on oil; and making large communities across the globe sustainable in terms of energy use.

Delivering the inaugural address, Prof. S R Hashim, Member Secretary, Planning Commission, Government of India, said that the use of RE sources in India is necessary, keeping in mind their capability to meet the needs of the rural population, their potential to supplement conventional power, and the fact that they are environment-friendly. He emphasized the need for capacity building in RETs at the educational and vocational levels.

Earlier, Dr Ramachandran said that REE must span the entire spectrum of the educational process from the primary grades through high school, technical schools, polytechnics, colleges, universities, and higher institutions. The attitudes inculcated at the school level will have a profound and direct impact on the public awareness of RE issues – for example, environmental concerns like deforestation, global warming, ozone layer depletion and climate change,' he said.

The proceedings of the symposium were summarized by the session rapporteurs in the valedictory session before a panel of the following experts:

1. Prof. David Mills
2. Prof. Yogi D Goswami
3. Dr. A Ramachandran
4. Dr R K Pachauri
5. Mr Rakesh Bakshi
6. Prof. H P Garg

A summary of each session has been included at the beginning of the respective sections of the proceedings.

The participants and the panelists discussed various issues related to the theme of the symposium and finalized the following recommendations.

1. REE has been covered very well at the university and college levels all over the world but attempts at school level at many places have resulted in some frustration. It has been reported during ISREE-6 that a lot of material for REE already exists at many places. There is a need to collate all the material at one place, and make it available to all institutions through appropriate media including the Internet. This material would then help fresh attempts for incorporating REE in curriculums at all levels.

2. Energy economics, which applies as much to economists as to the technologists, has not received the required priority, and there are few institutions imparting education in this field. Issues related to energy economics have therefore not permeated through the community. The economics departments of various institutions should include the teaching of energy economics in the syllabus.

3. Few training and awareness programmes are available for policy makers and elected officials of ministries – the persons responsible for finalizing programmes, policies, and financial resources for REE. Since REE is also related to employment and economics development, there is an urgent need to educate policy makers. For example, a module on RE can be included in the training imparted to young legislators in India, when they join parliament and other houses of governance.

4. REE requires geographical networking because the subject, apart from the specificities due to location, culture, and resource availability, also has generic characteristics. The panelists opined that, as an outcome of ISREE-6, a brief document should be prepared on the importance and status of REE and the strategies required to promote it to desired levels. This document should be widely disseminated. This will help in addressing and highlighting the issue of REE at all places through networking. The document should also suggest a tentative plan of action by which greater networking could take place among all persons dedicated to REE.

5. While formulating programmes and policies for REE, thought should be given to appropriate technologies for imparting education. The emerging information technologies offer enormous opportunities not only for institutions of higher learning or colleges/schools but also for schools of the kindergarten and primary levels. The values and interests, which are inculcated by students at initial levels through appropriate programmes, can be sustained over a period of time at higher levels. Children carry the knowledge and awareness to homes, and can become effective media for the education of parents. The profuse enthusiasm of students and teachers who participated in the competition, experiments, and other events of ISREE-6 clearly demonstrated this fact.

6. REE should also provide information and awareness about related topics like climate change, Montreal and Kyoto protocols, and recent conventions on climate change. People should be aware of the programmes aimed at the reduction in climate change and environmental pollution under the frameworks of the protocols.

7. Prof. David Mills informed that ISES could be helpful in disseminating information related to REE. The existing infrastructure (web sites, national sections, and the committee on education, etc.) is available for this purpose. For example, a database for the available and future teaching–learning materials could be compiled in Germany and disseminated worldwide. ISES would also consider publishing articles and journals to attract people from the education sector.

8. REE offers an excellent opportunity to the industry for interaction with academic institutions. Industry can sustain the interest of students and teachers in engineering institutions by informing them about the work being done on clean energy technologies. The interaction would encourage students to take up careers in the RE sector, thus ultimately benefiting the industry. Mr Rakesh Bakshi, Managing Director, Solchrome Systems India Limited and RRB Vestas, informed delegates that the industry is committed to help any institution to emphasize the importance and relevance of RE. He announced that one such programme has already been prepared for CREED (Centre for Renewable Energy Education and Development) at the Birla Institute of Technology and Science, Pilani.

9. Companies generally train their employees in various skills through apprenticeships and short-term training programmes. The companies were urged to include the information on RE use in such programmes. In addition, companies undertaking maintenance of RE systems and devices should include REE while training their workers.

10. Prof. Lars Broman urged delegates to make efforts to enlarge the membership base of the IASEE, by enrolling themselves with the association and acting jointly under its umbrella for the benefit of the people. It is the IASEE that organizes symposiums all over the world to create awareness about REE at different levels.

11. Dr A Ramachandran, who chaired the valedictory session and panel discussion of ISREE-6, requested Dr Ajay Mathur, Secretary, SESI (also Dean, Energy–Environment Technology Division, TERI) to lead a task force comprising Prof. H P Garg and Prof. M Ramachandran (with powers to co-opt). This task force would prepare an action plan to report the existing material available for REE, and frame recommendations for further efforts in making REE effective and universal. Dr A Ramachandran appealed to the RE community to make all the material and information available to the task force which will submit its report to IASEE within three months, and in India to the MNES, the Planning Commission, the AICTE, the NCERT, and other concerned organizations and funding agencies.

Annexure 1 Winners of the model/poster competitions

Model competition for schools

	Entry	Team	Name of school	Prizes given
First prize	Energy self-sufficient village	Ms Anjali Singh Ms Smita Gupta Ms Fauzia Zaidi	Mata Jai Kaur Public School New Delhi	PV lighting system (Solux II) with one lamp, one fan, and one FM radio set CD-ROM (Community PV - How you can use solar power)
Second prize	Fuel saving *tandoor**	Mr Sohan Singh Mr Anil Kapadia Mr Kulwant Singh	Ramgarhia Senior Secondary School Ludhiana	PV lighting system (Solux I) with one lamp CD-ROM (Community PV - How you can use solar power)
Third prize	Rotating solar cooker	Mr S S Parlikar Mr R P Deshmukh Mr Ramgarhia	Chhatrapati Shivaji Junior College Nanded	PV educational kit with full load CD-ROM (Community PV - How you can use solar power)
Special prize	Ocean Thermal Energy Conversion	Mr S D Jangam Mr Shailesh Zingade Mr Rahul Sood	Dr T B Cunha Government High School Goa	Model of wind energy converter (RRB Vestas) CD-ROM (The Sun's Joules-school energy doctor)

---

* A traditional oven in North India made from specially prepared mud and fired by charcoal

Poster competition for schools

	Entry	Team	Name of school	Prizes given
First prize	Think, ponder, and act	Ms Nirupama Ranjan Mr Manan Bibidal Mr Amit Tyagi	Laxman Public School New Delhi	PV educational kit with full load CD-ROM (Community PV - How you can use solar power)
Second prize	Indian Heritage Museum	Ms Anjali Singh Ms Amarjot Kaur	Mata Jai Kaur Public School New Delhi	PV educational kit with two loads CD-ROM (Community PV - How you can use solar power)
Third prize	Hydro-electric power - affluence from effluence	Ms Malini Suri Ms Ashima Makol Mr Akshay Sharma	Delhi Public School New Delhi	PV educational kit with one load CD-ROM (Community PV - How you can use solar power)
Special prize	Prosperity with renewable energy	Mr Arvind Kaul Mr Pankaj Nanda	Delhi Public School New Delhi	Model of wind energy converter (RRB Vestas) CD-ROM (The Sun's Joules-school energy doctor)

Poster competition for colleges

	Entry	Team	Name of school	Prizes given
Special prize	Sun - ultimate power and source of energy	Dr (Mrs) K Nanda Ms Rupa Walia Ms Anita Ravi	Daulat Ram College New Delhi	PV educational kit with full load CD-ROM (Community PV - How you can use solar power) CD-ROM (The green home - a new green way of building and operating your home)

Special session

Invited lectures

■

Ten years with the International Association for Solar Energy Education

Lars Broman

■

Global renewable energy education and training: World Solar Programme 1996-2005

Boris Berkovski

■

Trends and issues in renewable energy education

H P Garg

Special session of invited lectures: summary

Renewable energy education: current scenario and future projections
pp. 3–4

Chairpersons

- Prof. David Mills
  President, International Solar Energy Society, Freiburg, Germany
- Dr A Ramachandran
  President, Solar Energy Society of India, New Delhi

Rapporteurs

- Mr Amit Kumar
  TERI, New Delhi, India
- Dr S P Mohapatra
  UNESCO, New Delhi, India

Prof. Lars Broman in his presentation – *Ten years with the International Association for Solar Energy Education* – gave the historical background of the IASEE (International Association for Solar Energy Education). The rationale for starting these activities should be assigned to the education on solar energy as much as the use of solar energy. He spoke about the initiation of the IASEE in Sweden in 1989, its by-laws, articles, newsletters and international journal. He also spoke in brief about previous ISREEs (International Symposiums on Renewable Energy Education) and observed that ISREE-6 is probably the most successful ISREE so far, looking at the diversity of subjects covered, the number of organizations from different fields of RE (renewable energy), and the types of participants attending the seminar.

The second presentation – *Global renewable energy education and training: World solar programme 1996–2005* – was presented by Dr S P Mohapatra of UNESCO, India on behalf of Dr Boris Berkovski who could not travel to India due to his engagements in his office (UNESCO, Paris, France). The World Solar Programme has a wide scope, ranging from formal mode of education in universities and schools to informal modes, and aims also at educating policy makers and planners. The focus basically is transfer and sharing of knowledge and creation of awareness among people working with

RE. The strategy is incorporation of new technologies in curricular and short- and long-term training courses. A discussion was held on education material developed by UNESCO, comprising books, multimedia, and electronic programmes.

Prof. H P Garg, speaking on *Trends and issues in renewable energy education*, made the final presentation of the special session. In his own words, this presentation was aimed at creating controversies, which could then lead to international debate. He talked about even development index, which comprises health energy and all aspects related to REE (renewable energy education) including sustainability-related issues, and steps towards removing financial, institutional, commercial, and technological barriers to harnessing the resources.

He made a very strong point about the need for REE, and its requirements. Mentioning the fact that students interested in REE do not seem to have job opportunities after completing the available courses, he appealed that the following important aspects should be closely looked into:

- What is mode of education?
- What is the audience for whom the programme is to be designed?
- What should the duration of the programme be?
- How should the curriculum development take place?

Lack of learning aids in REE is an important constraint in the success and effectiveness of the educational programmes.

Solar Research
Centre, EKOS,
Dalarna University,
SE 781 88
Borlänge,Sweden

Lars Broman*, Konrad Blum, Sigge Niwong, Aadu Ott

Ten years with the International Association for Solar Energy Education

Renewable energy education: current scenario and future projections
pp. 5-10

Abstract

The idea of an international network first came up during and after the solar energy education session of the International Conference North Sun '88 in Borlänge, Sweden in July 1988. After much planning, including the making and mailing of a questionnaire, the IASEE (International Association for Solar Energy Education) came into existence in Göteborg, Sweden in December 1989. The IASEE was first governed by an organizing committee following provisional bye-laws. Permanent bye-laws were agreed upon during the first membership meeting – First World Renewable Energy Congress in Reading, September 1990. In the following months, the first Board of Directors was elected, and it took over from the organizing committee on 1 January 1991.

The following years meant a steady build-up of the IASEE, in which there was active participation by the authors. A newsletter, the *PiSEE* (Progress in Solar Energy Education) series and a discussion list on the Internet were created. A series of conferences and the ISREE (International Symposium on Renewable Energy Education) was also started. The present ISREE held in New Delhi, India is the sixth in order.

---

*Author for correspondence

Prehistory

The International Conference North Sun '88 took place in Borlänge, Sweden from 29 to 31 August 1988. At this conference, Broman and Ott presented a paper titled *Experiences from twelve years of teaching solar energy* (Broman and Ott 1988; 1989). In the concluding chapter 'International Cooperation', the authors wrote

> *Solar energy is a worldwide subject, and so is solar energy education. It is manifested by courses and seminars with international recruitment ... and publishing of textbooks ... International conferences frequently include a number of papers on solar energy education. Sun at Work in Europe (SAWIE) features the column Solar Education. These are good examples of means to communicate worldwide. We feel however that maybe more could be done to facilitate international cooperation between solar energy educators. We can think of a few other channels ...*
>
> - *A network of solar educators within ISES* [International Solar Energy Society].
> - *A computerized data bank with facts on textbooks, educational research articles, curricula, laboratory manuals, educational equipment, etc.*
> - *A newsletter and/or a Solar Education Journal.*
> - *Regional seminars, teacher training courses, etc.*

At the same conference, Blum presented the MSc course Principles of Renewable Energy Use offered at Carl von Ossietzky University, Oldenburg, Germany (Blum et al. 1989). The present authors discussed the topic raised in Broman and Ott's paper and decided to find out the possibilities of the formation of an international network. Broman subsequently conducted a survey by sending out a questionnaire to all North Sun '88 participants and handing it over to the participants in an Energy Educators Association Conference in Plymouth, Minnesota, USA on 5 May 1989. Some of the questions and answers are listed in Table 1.

In the fall of 1989, Broman had the chance to present the idea of an educational network in a plenum at the ISES Solar World Congress in Kobe, Japan (4–8 September). The idea was appreciated and many scientists expressed interest. Broman also discussed the possibility of making the organization an ISES working group on education with Douglas Balcomb as the chairman of the ISES Working Group Committee.

Next, a planning meeting was held in Borlänge. Konrad Blum, Lars Broman, Aadu Ott, and Chiheb Bouden from

Table 1 Results of Broman's survey

	Answers (%)		
Question	Yes	No	NA
Do you think an international network of solar energy educators should be formed?	89	4	7
Would you like to be a member of such a network?	86	7	7
Do you think a journal of solar education should be created?	79	14	7
Would you like to subscribe to such a journal?	79	7	14
Do you think international meetings of solar educators should be held?	75	11	14
Would you like to attend such meetings?	72	14	14

Tunis, Tunisia, participated in this meeting and suggested bye-laws for the would-be organization. Finally, a Foundation Meeting was held in Göteborg on 22 December 1989. Blum, Broman, and Ott participated in the meeting. Provisional bye-laws were taken and a temporary organizing committee (with Broman as Chair, Blum as Vice Chair, Ott as Secretary/ Treasurer, and Dr Reb Lal Datta from India, Dr Judith Pintér from Hungary, and Ms Joy Clancy from The Netherlands as members) and an Advisory Committee were formed.

First years

The IASEE was thus initially governed by an Organizing Committee, whose tasks were to market ISREE (International Symposium on Renewable Energy Education), to initiate activities, and plan a first membership meeting.

Blum took the responsibility of being the editor of the *IASEE Newsletter*, which was published four times during IASEE's first year. It continued to be published rather regularly, with Blum as editor for most of the years. Ott organized an IASEE Secretariat in Göteborg, which functioned till 1992, after which it was moved to Borlänge; and Sigge Niwong became the Secretary/Treasurer after Ott (who had to resign for other responsibilities). Niwong was in charge of the Secretariat through 1995.

Blum also initiated the electronic IASEE-L Discussion List on Solar Energy Education <IASEE-LISTSERV.GMD.DE>. After several years of operation, it still provides up-to-date information to several hundred subscribers all over the world.

The IASEE Advisory Committee initially consisted of Dr Nidal Al-Hamdani from Iraq, Prof. Salah Arafa from Egypt, Prof. John Duffie from USA, Prof. William Charters from Australia, and Prof. Kerr McGregor from Scotland.

During the first year, several other prominent solar energy scientists became members: Prof. William Beckman, USA; Prof. Martin Evans, Argentina; Prof. H P Garg, India; Prof. Terry Hollands, Canada; Prof. Leslie Jesch, UK; Prof. Boris Kazandzhan, USSR (now Russia); Prof. Kenichi Kimura, Japan; Prof. George Löf, USA; Prof. Joachim Luther, Germany; Prof. Boh Nabelek, CSFR (now Czech Republic); Prof. Folke Peterson, Sweden; Prof. A A M Sayigh, UK; Dr Harry Tabor, Israel; and Prof. Andras Zöld, Hungary. National contact persons were appointed for many countries throughout the world.

The First World Renewable Energy Congress held during 23–28 September 1990 in Reading, UK, had the following highlights. Firstly, the ISES Board Meeting unanimously accepted IASEE as the ISES Working Group on Education. Secondly, on 25 September, the First IASEE Membership Meeting was held in the presence of some 45 members. It was decided that from 1 January 1991 IASEE should be governed by a board of directors, to be elected by means of mail ballot during the fall. It was decided to have differentiated membership fees; higher (and in hard currency) for members from hard currency countries. Bye-laws were adopted, Article I of which is as follows

> *The name of the Association is International Association for Solar Energy Education, abbreviated IASEE. IASEE is a non-profit organization with the purpose to promote solar energy education worldwide by means of*
>
> - *publication of a newsletter*
> - *organization of international meetings*
> - *topical activities, and*
> - *being ISES Working Group on Education.*
>
> *Solar energy is here defined as direct use of the sun's energy and other renewable sources of energy (e.g., wind, biomass, hydro, wave power, Ocean Thermal Energy Conversion).*

During the fall of 1990, the membership reached 150, covering 40 countries worldwide. The following were elected to the first IASEE Board of Directors: Lars Broman, Sweden, President; Konrad Blum, Sweden, Vice President; Aadu Ott, Sweden, Secretary/Treasurer; Oliver Headly, Trinidad and Tobago, Director; Said Ibrahim, Egypt, Director; Judith Pintér, Hungary, Director; and John Twidell, UK, Director.

During the following years, the IASEE received a yearly grant of US $1000 from ISES. Membership rose to 400 members from 70 countries. The board was re-elected following nominating membership meetings during the ISES World Congresses in Denver, USA (1991); Budapest, Hungary (1993); Harare, Zimbabwe (1995); and Seoul, South Korea (1997). Ott did not contest in 1993; and Niwong was elected Secretary/Treasurer. Broman did not contest in 1995 and S C Bhattacharya was elected President in 1996, a post he continues to hold. Niwong did not contest in 1995 and the new Secretary/Treasurer from 1996 is S Kumar, Thailand. Blum did not contest in 1997 and the new Vice President from 1998 is Yogi Goswami, USA. The directors have changed over the years. The authors strongly believe that this is a positive development for the IASEE and are very confident that the association is in good hands now and for years to come.

ISREE and *PiSEE*

A series of symposiums has become an important part of IASEE activities. The 'First International Symposium on Renewable Energy Education ISREE-1' was chaired by Broman and was held in Borlänge during 19–20 June 1991. Fourteen papers were presented during the symposium, which was held in conjunction with the 'Nordic Solar Energy R&D Meeting'. The two joint meetings attracted 50 participants from 14 countries.

The proceedings of ISREE-1 were published in 1992 as Volume 1 of the publication series *PiSEE* (Progress in Solar Energy Education), edited by Blum and Broman. *PiSEE* has continued to publish papers presented at ISREE and contributed articles. From Volume 4, *PiSEE* became a referred journal with Jill Gertzén as its editor. Many Advisory Committee members and other solar scientists serve as referees for *PiSEE*.

ISREE-2 was chaired by Blum and was held in Oldenburg during 10–11 June 1992 with over 30 delegates. Thirteen papers were presented and subsequently published in *PiSEE* Volume 2 (1993). ISREE-3 was again held in Borlänge during 14–16 June 1993. Eight papers were presented at this rather small symposium, and they were published in *PiSEE* Volume 3 together with three contributed articles.

The large and successful ISREE-4 was held at the Asian Institute of Technology in Bangkok, Thailand during 12–14 December 1994, and chaired by S C Bhattacharya. Thirty-five of the presented papers passed the referee process, 15 were published in *PiSEE* Volume 4 (1996), and 20 in *PiSEE*

Volume 5 (1997). ISREE-5 was again held in Oldenburg in September 1996, and ISREE-6 is presently being held at the Tata Energy Research Institute in New Delhi, India. The IASEE has decided to hold the millennium's last ISREE–7, again in Oldenburg.[1] The ISREE series indeed seems to thrive.

Acknowledgements
The authors wish to express their sincere thanks to all the former and present members of the IASEE, its board and its committees, national contact persons, *PiSEE* referees, and organizers of and participants in ISREEs for their support and valuable contributions to the IASEE. (The authors will appreciate correspondence from other solar energy educators on issues raised in the present paper.)

---

[1] The next symposium (ISREE-2000) will be held in Oslo, Norway from 16–18 April 2000. – Editor

World Solar
Commission,
Engineering and
Technology
Division, UNESCO
1 Ruo Miollis,
75732 Paris
Cedex 15 France

Boris Berkovski

Global renewable energy education and training: World Solar Programme 1996–2005

Renewable energy education: current scenario and future projections
pp. 11–23

Abstract

UNESCO (United Nations Educational, Scientific, and Cultural Organization) with its Engineering Education and Training Programme is currently focusing its priorities on postgraduate training of energy engineering students (although much of the output is suitable for advanced undergraduates) and working engineers requiring retaining or updating. To meet the requirements, especially of educational materials, for developing countries and distance-learning purposes, multimedia learning packages are under preparation. They consist of textbooks, multimedia products, and software for self-training and distance learning. These are intended to train students in the field of renewable energies. Over half of the textbooks have already been published.

The packages will provide educational material of benefit to both industrialized and developing countries through a networking programme. They set goals for energy education that include environmental awareness, and ethical responsibility towards society and also contain student-friendly tutorials to enhance learning. This paper also addresses areas for priority actions in the various energy fields and presents UNESCO's philosophy for promoting energy education and training at all levels in the coming century. The WSSP (World Solar Summit Process) 1993–1996, can make a distinct contribution to the work of the UN and the system as a whole in support of sustainable development by focusing on the transfer and sharing of knowledge in the development of RE (renewable energy) technologies, according to the Secretary-General of the United Nations. The WSSP International Organizing Committee is chaired by UNESCO, and education and training in energy engineering has been designated as one of its strategic projects.

The World Solar Summit organized in Harare, Zimbabwe, in September 1996, launched the WSP (World Solar Programme) 1996–2005 and adopted the Harare Declaration on Solar Energy and Sustainable Development. WSP 1996–2005 was approved by the World Solar Commission at its second session held on 23 June 1997, within the framework of the Special Session of the UN General Assembly Earth Summit 5.

The learning packages mentioned above constitute an important contribution to this project. Areas for priority action to be proposed to the World Solar Commission are specified, including the assessment of specific education and training needs in the identified energy disciplines, and the capability of existing institutions to meet these needs. Specific measures to ensure that women achieve their full potential are recommended, including the expansion of scholarships and fellowships of in-country and foreign study and exchange of students and faculty.

> *Education must cultivate the ability to make informed choices basing judgements and actions not only on the analysis of present situations but also on the vision of a preferred future.*
>
> UNESCO International Conference on Education
> Geneva, 1994

The scope

Since engineering issues affect virtually every sector of all societies, very different sorts of people may find their education and experience inadequate to cope with problems connected to the introduction of new technologies. The scope of potential programmes of engineering education and training is therefore very wide, covering not only universities, research institutes, and technician-training facilities, but ranging from formal and non-formal programmes for high-level policy-makers and planners to activities designed to improve the understanding and acceptance of new technologies by the general public.

Clearly, that scope must include students currently enrolled in schools, colleges, and universities. The students who enter a university programme today will probably do their most effective work between 2000 and 2010 when by any estimate, new technologies will be more important everywhere than they are now. The basic sciences, engineering, agriculture, architecture, economics, political science, and other disciplines leading to research or practical careers in which technology issues will be paramount must, therefore, incorporate new technology considerations into their curricula; so also must trade schools preparing the technicians who will deal with new technologies.

However, attention cannot be focused exclusively on the present student population. New devices are ready for introduction right now; people already in the workforce must be trained to repair and maintain them. Government policy-makers and planners, governmental and non-governmental development field-workers, personnel in industry and commerce, agriculturists, and local entrepreneurs, all require appropriate training so they can make professional decisions compatible with national policy now and in the future. Most particularly, professional trainers and educators, including university faculty, may need technological training appropriate to their disciplines so that local educational institutions can better contribute to the solution of national problems.

In short, engineering education and training can be conceived as having both long-term and short-term goals, which are equally important. In the long term, the goal is to develop educated and skilled human resources, including specialists at all levels in all fields of engineering and generalists whose education includes an appreciation of how new technologies will figure in the fields they intend to pursue. In the short term, the goal is to re-educate specialists already in the workforce, including policy-makers, planners, educators and trainers, technicians, field-workers, industrial and commercial personnel, agriculturists, and other professionals and non-professionals. These goals require many different kinds of educative effort.

The mission

Investing in people through improving education is one of UNESCO's fundamental commitments. The entire education process must be linked more closely to real social life and must respect cultures as well as the environment. In this connection, the introduction into the curricula of knowledge, values, and skills relating to peace, human rights, justice, democracy, professional ethics, civic commitment, and social responsibility is given support and encouragement. Steps taken in this direction include the creation of UNESCO Chairs at various universities, major education projects for all regions of UNESCO, and the deep involvement of regional and international conferences of ministers of education, e.g., the 1994 International Conference on Education held in Geneva. A final asset is UNESCO's National Commission to promote all these programmes.

To meet the challenges ahead, the Engineering and Technology Division of UNESCO is focusing its programmes on WSSP 1993–1996, which assembled world leadership in September 1996 to launch a vast initiative for the development of renewable energies. One of the strategic projects of the WSSP is education and training in the field of energy engineering, with priority given to renewable energies. A similar concern was expressed at two recent major global conferences – The World Commission on Environment and Development in The Brundtland Report (1987), and the Earth Summit: United Nations Conference on Environment and Development (1992), both of which addressed the urgent need for human resources development for renewable energies.

The WSSP is a much-needed and vital activity for all those involved in renewable energies and the environment. According to the Secretary-General of the United Nations, the WSSP can make a distinct contribution to the work of the UN and the system as a whole in support of sustainable development by focusing on the transfer and sharing of knowledge in the development of renewable energy technologies. If it succeeds, it will create awareness of the importance of renewable energies, and of their intricate and intimate relationship to major environmental considerations. The WSSP is intended to achieve the same impact on society with regard to renewable energies as the Earth Summit did for the environment: fixed deadlines, standards, cooperation, incentives, pooling of resources, etc. As an added value, it will enhance worldwide employment by the development of new industries and consumers for the new products to be developed and marketed by upcoming industry. The WSSP is a response to the challenge posed by the Earth Summit which requires all countries to institute appropriate measures for reducing pollution by introducing clean energy technologies. Hence, the WSSP will set us off on the solar highway leading to sustainable development.

As we look towards the future, UNESCO, with the help of the UN, and the cooperation of specialized agencies and programmes, many international, national, and regional organizations, non-governmental organizations, such as its own World Federation of Engineering Organizations, and the International Union of Technical Associations and Organisations, industries, and professional/trade organizations will develop and implement activities and provide services such as those described below.

Long-term education and training for energy engineers

There is a place for RE education throughout the schooling process, from the primary grades through high school, technical schools, and universities. This carries with it the need for identification and training of teachers for each of these levels, as well as the preparation of curricula and teaching materials dealing with energy.

In some developing countries, especially in rural areas, a primary-school focus is particularly important, for this may be the only formal education children receive. The attitude towards energy inculcated at this time might have a profound effect, not only on the students, but also on parents who follow their children's school work. This can directly impact the general public's understanding of, let us say, the fuelwood problem and the need for innovation in stove design and solar crop-drying techniques.

In many developing countries, secondary education is used to impart job-related trade skills, as well as to prepare for college. Programmes on the maintenance and repair of RE devices and the adaptation of non-local designs to local needs and materials should be introduced into high schools and technical schools. This will not only provide societies with the skilled technical human resources needed to make the introduction of RE technology feasible, but it will also impart income-earning skills for a new era of energy use. Here again, training material equipment is needed and teachers must be trained in its use.

It is probably desirable throughout the educative process, but particularly at the university level, that RE considerations in general be placed in the development context, both rural and urban. RE is more likely to receive its proper due if considered at par with other supply options so as neither to exaggerate nor to underestimate its potential importance to any locals. Beyond this, the impact of energy issues on each economic sector and on inter-sectoral coordination needs to be clarified and emphasized.

RE education at the university level must address both the scientific and technical issues and also the interdisciplinary issues drawing on all relevant fields. This suggests the introduction of curricula both in departments of basic sciences, engineering, agriculture, architecture, etc. as well as in social sciences and humanities. Great care must be taken in the creation and modification of courses and the development of educational materials, and special attention must be paid to depositing energy-related materials in university libraries, equipping laboratories, and stimulating research. The last is particularly important although there are notable exceptions; many developing-country universities are weak in research in science-related fields, in part because of the expense involved. This is particularly dangerous where RE is concerned, because a great deal of the relevant technology is site-specific and needs to be tested and evaluated in the setting within which it will be used.

There is a growing need for special research facilities concerned with both renewable and conventional energies in most developing countries. These are probably best developed in existing institutions, where they will both strengthen and be strengthened by the ongoing work of those institutions. Precaution should be taken in the creation of new institutions lest they become isolated from the mainstream educative effort and draw away expert personnel, which are anyway in short supply in developing countries. However, regional or sub-regional research and laboratory facilities might be more cost-effective.

Short-term education and training for energy engineers

Probably the first priority for short-term education and training is the re-education of teachers in all fields. Training the trainers requires a starting point: foreign consultants of field-workers, trained teachers, or autodidacts. At least an initial assessment of teacher-training resources is necessary to begin an RE education programme.

Training of university faculty may have to be extensive, including the acquiring of advanced degrees. In the present climate of a developing country, higher education may mean attending foreign universities, with an attendant need for scholarships and fellowships. But keeping university faculty attuned to the state of the art also means building library collections and encouraging research, arranging for inter-faculty and inter-institutional communication, and providing for professional associations. The thorough development of indigenous RE experts must be treated as an ongoing process and financed accordingly.

Another urgent need is to provide officials in charge of energy policy and planning with the technical and economic background to perform their tasks through a series of special courses, initially on the international and regional levels. It is estimated that the training of some 300–500 high and middle-level officials each year would significantly strengthen the capacity for planning and management of the energy transition.

Extension courses and short courses for teachers, government officials, field-workers, agriculturists, and private sector personnel have been developed in many countries. These should be studied so that new teaching methods and curricular materials can be most efficiently diffused. There is also a need for a broad programme to promote public understanding of the energy situation, especially for the rural populace and women. This will require special materials produced in formats suited to the audience in question. A number of institutions are undertaking projects to study, among other things, proper formats for RE educational materials intended for a wide variety of developing-country audiences. The results of these and of related public education efforts in other fields should be examined and used where appropriate.

A first step towards creating a new breed of energy engineers

UNESCO has launched a unique energy engineering learning package that targets advanced undergraduates and postgraduate engineers. This learning package is being designed to provide the type of multimedia educational material for postgraduate energy engineers that will benefit both industrial and developing countries through a programme of networking between individuals, industry, and educational institutions. In addition to providing up-to-date subject material prepared by leading experts, and improved methods of instruction in the different fields of energy engineering, UNESCO's learning package sets new goals for engineering education combining

- technical and scientific excellence,
- economic viability,
- environmental awareness,
- ethical responsibility towards society, and
- student-friendly tutorials to enhance learning.

These new criteria must help developing nations and emerging economies to achieve greater self-sufficiency and an improved standard of living. In the end, the new generation of energy engineers will benefit us all through a new vision and awareness of their role in society.

UNESCO's understanding of the interconnection between science, technology, and society results not only from its role as the interdisciplinary agency of the UN, but also from its singular and delicate constitutional responsibility to reflect the will and concerns of its 181 members.

As a forum for scientists, engineers, teachers, and artists through their particular professional organizations, essentially providing a bridge between the specialist and the decision-maker, UNESCO's goal are to improve and widen technical education opportunities. These goals are sought by rethinking and reviewing teaching methods and materials to develop active partnerships between individuals, institutions, and governments on a local, national and global scale; to enhance the transfer of technologies from the developed to the developing countries; and to raise and unify standards universally, by such means as networking, distance education, teleconferencing, lifelong learning, and self-training using advanced technologies.

Environmental tragedies such as the decimation of the Amazon rain forest, increased emissions of CO_2 into the atmosphere and, the recent nuclear and ecological catastrophes in the Soviet Union and elsewhere have reinforced UNESCO's determination that new criteria shall be set for the education of future engineers.

Why postgraduate training first

Many developing-country scholars who proceed to do postgraduate work obtain their advanced degrees at developed-country universities (and possibly add to the brain drain phenomenon). Since this situation is not likely to change for some time, scholarship and fellowship programmes will be required to allow graduates to go abroad. At the same time, national institutions are being strengthened and faculty re-education will be facilitated if programmes are initiated to bring experts from other universities, in both developed and developing countries, perhaps through exchange fellowships, and to encourage exchange of faculty. For the successful treatment of RE considerations at the college level, emphasis should be on the development of novel learning and teaching materials in engineering for the postgraduate level. UNESCO's aim to promote universal standard will therefore be more readily achievable.

A standard-setting reference

To develop the energy engineering learning package, UNESCO is using state-of-the-art and low-cost communications, computing, and data storage techniques. Each course makes use of a mix of media adapted to the needs of the subject. These include written texts, audio-visual material, face-to-face tutorials, lectures, and supervised laboratory work. Special attention is given to the development of interactive self-assessment software.

Extensive reference material – statistics, bibliographies, graphics, models, etc., – enabling the student and tutor broad scope to draw up a syllabus appropriate to their particular needs, and a wide range of subject matter from which to select those components that are considered locally important while at the same time promoting harmonization of standards and regulations.

A code of ethics: emphasizing society and the environment

While continuing to train postgraduate engineers in the latest advances in the field, giving due consideration to technical and economic problems, UNESCO's learning package introduces into the curricula a knowledge of values and skills relating to social responsibilities and cultural elements, especially environmental consequences of the engineer's actions. The plan is to effect a dramatic shift towards greater moral and ethical responsibility in this new generation of engineers and decision-makers both as individuals and as a professional group.

Awareness of personal responsibility is linked to the recognition of the value of civic commitment. It is a new strategy to foster sustainable development and protection of the environment by educating responsible technologists to recognize and accept the values which exist in the diversity of individuals, peoples, and cultures and develop the ability to communicate, share, and cooperate with others.

Bridging the gap: education versus industry

For both developing and developed countries, the UNESCO energy engineering learning package is a response to the demands of industry. It is appropriate for use in any academic institution which has the required laboratory and workshop facilities – but not necessarily the skilled specialist staff. The package encourages initiative and promotes responsibility, self-discipline, and proper study habits in the student by emphasizing practical applications and problem solving, while retaining a strong theoretical base.

Equally, as a teaching/learning tool for continuing education at the work place for engineers wishing to update their skills, this multimedia package offers the following advantages:

- Relevance: the courses are designed to enable technical staff to update their knowledge and skills without the disruption of leaving work to attend external courses.
- Flexibility: multimedia-based courses allow employees to study and retain their commitments to company projects, and to select modules which meet specific needs.
- Economy: companies do not have to pay for outside study courses and can reuse the teaching/learning material many times over.

What's in the package?

The text of about 11 modules on RE and energy conservation has been completed, and so far half have been published commercially. A project has been launched to develop prototype multimedia CD-ROMs for each of the modules over the next two years. The courses emphasize the practical aspects of the subject matter being treated, and include examples of their application to a variety of RE technology systems while giving the student exposure to the field of energy planning and policy by providing the fundamentals of energy economics and modeling.

Additional courses, stressing environmental protection and ethics, form part of the package. Each section of the package will also be published on floppy disks, and the entire programme will be recorded on CD-ROM, for easy computer access. Table 1 shows the structure of the package.

Video-related textual support on CD-ROMs for students includes a narrative connecting all points made in the text with equations and figures, a list of academic objectives, problems to be solved, and a reference list. Thus, the CD-ROM is backed up by study texts and other media such as software-based lessons or audio tapes. They could be viewed by the students meeting as a group for this purpose in the presence of a tutor who would lead the discussion of the tapes at the end of each session. This discussion is seen as a potentially integral part of the learning process.

UNESCO will use a CD-ROM version in which the textual component is relatively high so as to give a permanent individual record of key ideas, and provide an explicit statement to students of what new skills they should be able to employ on completion of the course. In addition to CD-ROMs covering each principal presentation, there are plans for tapes showing problem solving and tutorial or discussion sessions, and others giving an academic overview and review of the course.

Table 1 Structure of the learning package on renewable sources of energy

Module designation	Year of completion	Hours
Renewable sources of energy		
Biomass conversion technology[a]	1996	20
Energy from waste[c]		10
Fuel cells[c]		10
Geothermal energy[a]	1995	10
Hydrogen[c]		5
Magneto-hydro-dynamic power generation[a]	1995	10
Maintenance of renewable energy equipment[c]		15
Mini-hydropower[b]	1996	10
Ocean thermal energy conversion[a] (includes other forms of ocean energy)	1996	5
Solar desalination[c]		15
Solar electricity[a]	1994	15
Solar ponds[c]		5
Thermal energy storage[c]		7
Wind energy[b]	1996	10
Planning and policy		
Energy and society[c]		10
Energy planning and policy[a] (includes energy planning methods, techno-economic evaluation of renewable energy technologies)	1995	60
Energy conservation		
Energy conservation for agriculture[c] (includes energy audits)		20
Energy conservation for transportation[c] (includes energy audits)		20
Industrial energy conservation[a] (includes energy audits)	1996	20
Residential and commercial energy conservation[c] (includes energy audits)		20
Energy and environment		
Environmental management[a] (3 volumes; published in conjunction with another programme)		
Environmental technologies[c]		7
Code of ethics		
Code of ethics for engineers[c]		7

[a] Published; [b] To be released shortly; [c] Under consideration

New interactive multimedia software related to each lecture enables students to train themselves and to assess their own progress. Each CD-ROM sets out specific objectives amounting to a detailed statement of the courses' intent. There are two types of assessments: one, to measure the student's understanding of the information contained in the lecture, and another, to assess the student's ability to put that understanding to practical use through the completion of specific tasks assigned by the tutor.

This part of the package will contain materials to be used in the advanced learning stage as a tool for design, assessment, and selection of specific equipment and energy systems. It is accompanied by tutorial instructions to assist tutors in the exercise and use of the respective courses.

The UNESCO/ISEEK Energy Database

Complementary to the learning package, there exists a UNESCO/ISEEK (International System for Energy Expertise and Knowledge) database. This contains information on 4000 research institutions involved in RE technology as well as government agencies, trade and professional associations, training institutions and courses, networks, databases and journals, reference publications, audio-visual aids as well as an expert file at a later stage. The 1993 version of the database is available in both print and CD-ROM versions.

Areas for priority action

Being concerned by the urgent need for development of a new educational process on RE sources to maintain their increasing utilization in both the developing and industrialized world, being mindful of UNESCO's responsibility for the education especially of energy engineers committed to the promotion of peace, human rights, and democracy, and being convinced that education should promote knowledge, values, attitudes and skills, conducive to the building to a culture of peace and democracy, the following priorities are suggested.

Assessment

There is a need to understand the specific education and training requirements in the various energy areas which have been identified, and to assess the capability of existing institutions (national, regional and international) to meet those needs.

Restructuring

Wide penetration of the education programme and the attainment of its objectives must be achieved by employing new teaching methods, open and flexible methodologies, and inexpensive teaching material. Consequently, it is necessary to develop and distribute novel and appropriate teaching material, curricula, and teaching aids to facilitate training in all areas, in particular, new technologies, with a view to educate responsible engineers, who are open to other cultures.

Education and training

There is a need to adopt measures to enhance the role of informal and non-formal education, to give priority to pre-service and in-service training, and to retrain educational personnel including:

- policy-makers and energy planning specialists,
- technical specialists including engineers, scientists, and technicians,
- field workers, extension workers, and local administrators,
- teachers at all levels, and
- the public.

This can be done by the establishment of programmes to promote and improve understanding energy, preferably within a broader programme of understanding of the role of resources in development.

Scholarships and fellowships

There must be review, and where appropriate, expansion of scholarships and fellowships for in-country and foreign study and exchange of students and faculty, in particular, women. Specific measures must be taken to ensure that women achieve their full potential.

Low cost

Emphasis must be on the maintenance of low costs, without lowering standards, of all educational and training material as well as tuition by adopting a standardized approach acceptable to the world's funding agencies.

Centre for Energy Studies,
Indian Institute of Technology,
Hauz Khas
New Delhi - 110 016
India

H P Garg*, T C Kandpal

Trends and issues in renewable energy education

Renewable energy education: current scenario and future projections
pp. 24-30

Abstract

This paper discusses some important issues related to REE (renewable energy education) in developing countries. These include: (1) the need for matching curriculums with manpower requirements, (2) ensuring synergy between energy and environment education, (3) consistency and coherence in inputs being provided at different levels, and (4) employment aspect(s) of REE.

---

* Author for correspondence

Introduction

Availability of cheap and abundant energy with minimum environmental and ecological hazards associated with its production and use is one of the most important factors for economic growth and also for the desired improvement in the quality of life of the people living in developing countries. However, only after the first oil crisis of the early 1970s, was the importance of energy appreciated on a global level. The oil-importing developing countries have been facing multifaceted problems in this regard – of course, the worst being the problem of balance of payments. More recently, the adverse environmental implications of excessive production and use of fossil fuels have also been noticed in certain parts of the world. Obviously the developing countries are facing quite a challenging task – that of increasing energy production and use for improvement in the physical quality of life of billions of their people and simultaneously trying to reduce the financial burden on their economies due to increasing fossil fuel imports. Two important strategies are being adopted by a number of countries around the globe. The first strategy calls for energy demand management, which effectively means promotion of various energy efficiency measures, and the second approach is the development and large-scale dissemination of RETs (renewable energy technologies). Though the adoption of energy efficiency measures is necessary in the first instance, their effectiveness is limited by the fact that these measures only reduce the demand and do not augment the dwindling supply of fossil fuels. Moreover, the marginal cost of saving an additional unit of energy normally increases. On the other hand, harnessing RE (renewable energy) sources can significantly augment the energy supply and these normally have economies of scale. Thus, the development and dissemination of appropriate RETs is quite crucial for meeting the increasing energy requirement in these countries.

Need for renewable energy education

Many countries around the world took initiatives for the development and dissemination of RETs immediately after the first oil crisis. However, in spite of ambitious programmes of many countries in this direction, the dissemination of these technologies has not met the expectations of the planners and implementing organizations. There have been only a few successful cases of the adoption of RETs.

The poor dissemination of RETs may be attributed to several factors. One of the important inhibiting factors is the lack of a structured framework for providing energy education, in general, and REE, in particular. For example, in many countries, the lack of indigenous technology development capability in the area of new and renewable sources of energy has often resulted in the promotion of very expensive and inappropriate designs. Similarly, in some other places, owing to the unavailability of local technical manpower for proper repair and maintenance of the initially installed systems, the users have decided to use some other energy resource–technology combinations. Some of the RETs were not accepted by the end-users as they were unaware of their potential benefits and associated requirements. These and several other such problems are merely manifestations of the same root cause – lack of proper REE.

Levels of renewable energy education

The need for REE and training has to be tackled at several levels. For creating awareness and interest among the public and also for providing first-hand exposure to the basic concepts and their applications, relevant inputs will have to be introduced at the school level. Short-term courses and the use of mass media techniques can also help in achieving the above objectives. Diploma level courses will have to be introduced for training of personnel in fabrication, installation, and maintenance of energy technologies and systems. Regular four-year bachelor degree courses in energy engineering with specialization in the area of RE and energy conservation may be required for providing the required manpower for design development and evaluation of emerging technologies. Teaching and training programmes at the postgraduate level can be useful in imparting advanced level inputs to engineering graduates or science students preferably with certain specialization options. Finally, short-term mid-career training of scientists, engineers, policy-makers, and administrators in certain specific aspects may also be required. It must be emphasized that for effective and large-scale dissemination of RETs, initiating and strengthening efforts at all the above levels is equally important.

Renewable energy education in India

During the past two decades or so, REE efforts have primarily focused on postgraduate level teaching/training programmes. IIT (Indian Institute of Technology), Delhi, was the first institution in India to start an M. Tech. programme on energy studies as early as in 1981. Since then, many other institutions have started offering postgraduate level teaching programmes and courses in the area of RE. The National Council of Educational Research and Training has attempted to introduce basic concepts about RE sources and technologies in school curriculums. A B. Tech. programme in energy engineering is being offered at IIT, Kharagpur. Several other undergraduate engineering degree programmes on RE are offered. Short-term training/refresher courses are also being offered besides a large number of seminars/workshops/symposia/conferences being organized on RE and related topics. Some work has recently been initiated towards the development of vocational courses and courses for technicians and mechanics.

Important issues in renewable energy education

As mentioned earlier, REE and, for that matter, even energy education are relatively recent initiatives. Moreover, being an interdisciplinary and end-user driven field (except large-scale grid connected power generation), a variety of new issues must be properly addressed to make the educational efforts in the area efficient, effective, and economically viable.

Synergy between energy and environment education

In the prevailing situation of increasing environmental consciousness, it is very likely that all potential energy solutions will be rather strictly guided by their short- and long-term effects on environment and other sustainability-related aspects. It is crucial for all the energy resource–technology combinations (envisaged to be used for meeting the future energy requirements of the global society) to be environmentally sustainable. Therefore, adequate inputs regarding the ecological and environmental implications of different energy resource–technology combinations must be provided as a part of energy education to ensure that sustainable energy paths are developed and disseminated. Conversely, efforts towards imparting environmental education must ensure that adequate inputs are provided to the students so that they are able to undertake in-depth assessment and evaluation of various potential energy supply options to meet the increasing energy demand of humanity. Moreover, they should be able to suggest remedial measures wherever required to minimize the adverse environmental impacts of the energy solutions opted by the end-users. It is, therefore, necessary that inputs for both energy and environment education are provided in a synergetic manner. Extraction, conversion, and utilization of energy sources being the primary causes of environmental degradation, it is high time that both energy and environmental planning efforts are made in cohesion.

Continuity and consistency in renewable energy education

Another dimension of energy education, in general, and REE, in particular, which merits immediate attention is to ensure continuity and consistency in the inputs given at different levels. Incidentally, immediately after the oil crisis of the early 1970s, more emphasis was given to university level courses with even more prominence to postgraduate level courses. As a result, the inputs provided in these postgraduate courses necessarily included very simple introductory concepts, definitions, etc., as well as advanced inputs. With the realization of the fact that REE has to be imparted at other levels as well, teaching programmes at lower levels were also initiated in due course. While specialization/elective courses are offered in undergraduate degree programmes, efforts have also been made to introduce relevant concepts at the primary/secondary/senior secondary levels. Some efforts have also been made to offer certificate/diploma level courses in these areas for mechanics and technicians and also to introduce these topics in relevant vocational courses. However, for a variety of reasons, the above efforts have been very disjointed and unable to ensure the overall continuity and consistency in the inputs provided in various courses at different levels. For example, there is no conscious effort to ensure that the basic definitions and concepts being introduced at school level are not repeated in the university courses. There is an urgent need to develop a comprehensive structured framework for providing REE at different levels and for different target groups in an efficient and effective manner. While maintaining continuity in the inputs gradually provided at various successive levels, efforts should be made to avoid any repetition. In cognizance of the fact that a student can adopt a variety of routes to acquire higher levels of skills and knowledge (besides degrees/diplomas/certificates), it is crucial to ensure that the necessary inputs are provided in a gradual manner in all possible routes.

Renewable energy education and employment

In order to ensure that the share of renewables in the supply mix of different energy sources is substantially increased, large-scale dissemination of RETs is necessary. This will lead to an increase in the required number of suitably skilled manpower to design, develop, install, repair, and maintain RE systems. An important characteristic of RET development, dissemination, and utilization is that it leads to manpower requirements at two distinct levels. While the centralized large-scale harnessing of RE sources (such as electric power generation using solar, wind, geothermal, waves, tides, ocean thermal gradients, mini hydro, etc.) and large-scale industrial process heating applications would, in general, provide employment opportunities in the organized sector, the decentralized (invariably household-level) applications of these sources (improved cookstoves, solar cookers, biogas plants, solar photovoltaic lanterns, solar domestic hot water systems, etc. have immense potential for creating skilled manpower requirements usually centred around private/individual entrepreneurs. To meet the manpower requirements of both the above types of potential RE applications, it is important that educational efforts in this area take into account the job requirement of both types of applications. REE must, therefore, ensure that trained manpower for large-scale systems is available along with skilled entrepreneurs for design, development, trouble shooting, and maintenance of decentralized systems.

Approaches for imparting renewable energy education

Human resource development efforts to provide the required manpower for design, fabrication, installation, operation, and maintenance of various RETs and systems can be made in several ways. In one of the possible approaches, which was essentially adopted immediately after the first oil crisis of 1973 and is still being followed, scientists and engineers from relevant (sometimes called parent) disciplines can diversify into the field of RE by either acquiring additional inputs by self-study or through suitably designed education and training programmes. Alternatively, specialized energy engineers, scientists, technicians, and mechanics can be trained to meet the associated challenges. Both these approaches have associated merits and limitations and it is necessary to further evaluate and study the implications of each of the routes as long-term strategies for REE.

Trade-off between breadth and depth of renewable energy courses

In most REE programmes, often a trade-off has to be made between the breadth and the depth of a course. For example, if a single course (of about 45 contact hours) is expected to provide inputs on all different RE sources such as solar, wind, biomass, hydro, geothermal, ocean thermal, waves, tides, etc., it is but natural that only basic concepts (knowledge and understanding level) are introduced in the course and detailed treatment (designs, analysis, evaluation, etc.) is usually not possible.

As a consequence, even after successful completion of such a course the students are only aware of different possible technological options for harnessing renewable sources of energy but are not able to acquire competence for their design, fabrication, performance evaluation, etc. This has, in the past, led to a variety of problems since manpower with half-baked knowledge is unable to prepare and implement a structured holistic strategy for large-scale sustainable dissemination of RE systems. In fact, in many cases, their efforts have resulted in distorted prioritization and non-judicious allocation of scarce resources and funds.

Issues related to curriculums

A careful analysis of the course contents of many teaching/training programmes on new and renewable sources of energy reveals that more often than not the curriculums are strongly driven by the expertise of available teachers rather than the inputs to be given to the students. Due to these compromises: (1) the students are not given the desired inputs, and (2) the areas in which expertise is available are often given undue importance thus introducing unwarranted biases in the minds of the students.

A proper balance between theoretical and practical inputs is crucial for any REE programme. The laboratory component of RE courses must ensure enough hands-on training of the students. There is an urgent need to develop suitable experiments which can be offered at different levels.

Unavailability of books and other teaching-learning aids

Unavailability of good quality textbooks and other teaching–learning aids at reasonable prices is another important bottleneck in providing proper REE. It causes considerable problems to students. Moreover, in the absence of a standard textbooks, the coverage of a course predominantly depends upon the expertise and biases of individual teachers.

Conclusion

REE must be taken very seriously, as its present status is far from satisfactory. In fact, any half-hearted effort in this direction would do more harm than good. Concerted efforts must be made to impart REE in a comprehensive manner.

Acknowledgements

The authors are grateful to United Nations Educational, Scientific and Cultural Organization's Regional Office in New Delhi for providing financial support for a variety of activities in the field of renewable energy engineering education.

Session I

Renewable energy education policy/ Curriculum design/Case studies

◆

Renewable energy in university physics teaching
Arne Auen Grimnes

◆

Creating a European Solar Engineering School
Lars Broman

◆

Design and teaching of a course on renewable energy at Birla Institute of Technology and Science, Pilani
M Ramachandran

◆

Designing packages for renewable energy education
Anitha Saravanan

◆

Present status and future direction of renewable energy education in Bangladesh
M A R Akhanda

◆

Impact-oriented comprehensive approach for energy education
Jyotirmay Mathur

◆

Teaching of wind energy at advanced undergraduate and postgraduate levels
Kunal Ghosh

◆

Renewable energy training for desert development
Salah Arafa

Renewable energy education policy/ Curriculum design/Case studies: summary

Renewable energy education: current scenario and future projections
pp. 33-34

Chairperson
- Prof. H P Garg
  Indian Institute of Technology, New Delhi, India

Rapporteurs
- Dr T C Kandpal
  Indian Institute of Technology, New Delhi, India
- Mr Amit Kumar
  TERI, New Delhi, India

Prof. Y D Goswami started his presentation by building a case for RE (renewable energy) in the increasingly problematic energy–environment scenario of the world. He dealt very effectively with local warming effects that are recognized well in the world. This shows that RE is a very important alternative for the kind of energy pact we have right now. He went on to describe different RES (renewable energy sources): wind, biomass, solar, etc., and how they could be used for various industrial applications and uses in remote areas.

One of the applications that he talked about was solar degasification, which is now becoming very important in the industrial sector, especially in industries like textiles, paper, pulp, distilleries, chemicals, and so on. Also he discussed the RE issues most often talked about, i.e., cost and renewability. However, he showed that both aspects are becoming better everyday; costs are going down and renewability is going up gradually. On the main issue of REE (renewable energy education), he felt that the present level is neither adequate not properly directed. He stressed that REE needs to be imparted at various levels - from universities to colleges to schools to very basic levels. At the same time, he emphasized the necessity of educating public policy makers in various aspects of RE.

The second speaker, Prof. David Mills, started by touching upon the topic of global warming. He explained the various benefits and applications of solar energy and emphasized that by 2010, two per cent of global energy would be sourced from RES. He mentioned that about 9000 GWhr could be generated from various RES. Answering a question by Dr A Ramachandran about the effectiveness of the Internet and other information technology tools that are now fast gaining prominence, he said that these tools could be used very effectively to propagate and impart REE.

The third lecture, by Prof. Mohammed A R Akhanda from Bangladesh, was essentially on the status RE in Bangladesh. Having started in the early 1950s, REE is imparted by nine state universities and four technological institutes in Bangladesh. They offer a variety of undergraduate and postgraduate courses on select subjects, but these courses are mostly under general science subjects. Bangladesh Open University offers some non-formal education including REE.

Arne Auen Grimnes from Norway, presenting the fourth and last lecture, gave a study of Norway's scenario of RE and environmental education, mentioning that Scandinavian countries are very advanced in environmental consciousness and the use of RE. He said that generally there is a five-year programme on environmental physics, which covers both physics and the specific environmental part. He suggested that students want more and more of the environment aspect, which indicates the increasing environmental consciousness among students. One of the major tools they use to learn technology is experiments. The study is very job-oriented; in fact, that is the main motto of REE in Norway.

Dr Lars Broman described the European solar energy school, which is where they are proposing a series of short and long courses in solar energy education. Dr M Ramachandran is already a coordinator on RE in Birla Institute of Technology and Science, Pilani.

Dr J Mathur said that in the Indian Institute of Technology, New Delhi, courses in RE are being planned. A common thread running through the various presentations was to catch them young, to inculcate interest from the very early stages. Dr Mathur proposed a five-tier educational system where RE awareness is initiated from the primary stage.

Dr Ramachandran reiterated that RE should be inculcated in the minds of young engineers so that they can focus on solving real-life problems when they take up jobs. Also, education in engineering should have an application-oriented approach and forge more links between industry and colleges.

Finally, Ms Anitha Sarvanan, TERI, emphasized that the designing of RE packages at school levels should consider the teacher–taught relationship and the teaching–learning processes. A combined strategy should be worked upon to bring out the desired effect, keeping in view the implementation of the subject matter.

Agricultural
University of
Norway, P B No.
5065, N-1432
Aas, Norway

Arne Auen Grimnes*, Petter Hieronymus Heyerdahl

Renewable energy in university physics teaching

Renewable energy education: current scenario and future projections
pp. 35-41

Abstract

At the AUN (Agricultural University of Norway), a programme called Small-scale Energy Technology is under way. The main aim of the programme is to allow physics and engineering students to design and build a demonstration site on renewable energy for future students and visitors. The site is managed and developed further each year by students in cooperation with scientists.

Currently, five projects are running within the programme. These are:

- Photovoltaic system fueling an electrical bicycle
- Solar heat exchangers for domestic hot water production
- Vertical wind turbine
- Combined heat and power production from biomass
- Solar kitchen

---

*Author for correspondence

Environmental physics at the Agricultural University of Norway

The AUN is situated at Aas, 30 km south of Oslo (*for details on global solar irradiance in southern Norway, see Annexure 1*). The university offers five years of masters level tuition to 2300 students, and the option of an additional three years' Ph. D. study. Research includes activities ranging from food science to landscape architecture, and from biotechnology to environmental physics.

An education in environmental physics consists of three years of 'normal' physics, mathematics, computer science, biology and chemistry. In the last two years, students specialize and take their diploma degree or their masters degree in biophysics, micrometeorology, renewable energy, fluid transport processes in porous media, etc.

Small-scale energy technology

At the Department of Environmental Physics, a programme called Small-scale Energy Technology is under establishment. The main objectives of the programme are to:

- design and build a demonstration site on renewable energy for future students and visitors,
- run and develop the site each year in cooperation with scientists,
- allow new students to learn physics and data acquisition through practical applications,
- let undergraduate students have a 'taste' of the 'environmental' side of physics, which they will meet during their later masters studies,
- use the results and the students who work on the projects to promote the university,
- introduce students to the development of renewable energy equipment for industrialization, and
- encourage students to have fun while they learn.

Currently, five projects are running within the programme.

Sunbike

In April 1997, the students finished the first stage of the Sunbike project. A bike with a built-in electrical motor was bought from Germany. The students used our database with local solar radiation data to dimension a solar charging system for the bike. PV (photovoltaic) panels, accumulators, controllers, etc. were bought according to their plans, and the students assembled the parts themselves (Figure 1). They also wrote a manual explaining the use of the charging system.

The solar-powered bike became widely known throughout the university campus within weeks of its first presentation. This led to considerable media interest and within half a year, the Sunbike had appeared in 10 newspaper articles, on three

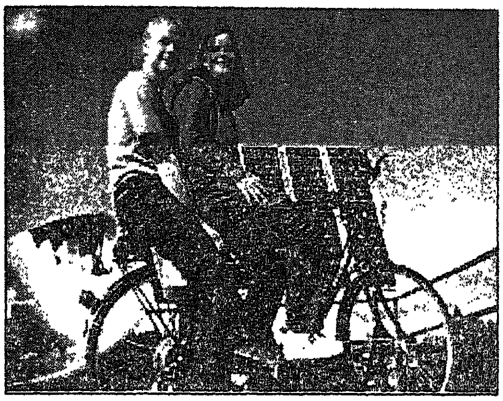


Figure 1 Students on the electrical bicycle in front of the PV panels and the solar oven on the roof of the university laboratory wing

radio programmes, and featured in one regional and three national television programmes. Additionally, Sunbike has been shown at six fairs and exhibitions, has received the first prize in a solar energy competition for students, and has been demonstrated to countless other people. The charging system and the photovoltaic panels have been integrated in a bike garage, the so-called 'Charging Dairy' which can be transported on a car trailer. In this way, the Sunbike can be used for public relations exercises.

Staff from our information department and student representatives can take the bike on visits to regional education fairs for pre-university pupils. Alternatively, the students themselves can visit schools where they demonstrate the Sunbike, and also make presentations about the interesting work going on at the university.

Solar heat exchanger system for domestic water heating

In the spring of 1998, first level physics students have dimensioned and assembled a solar heating system for domestic hot water supply. They have also started to develop a logging system to monitor the energy flow. The work has been done as a part of a physics laboratory course. The system now supplies hot water for the laboratory wing at the institute Figure 2.

The pedagogical importance of exploiting the harvested energy for a practical purpose is obvious. The participating students who work with the solar hot water system, as well as other students who use the building, can experience the results every time they open a hot water tap in the laboratories.

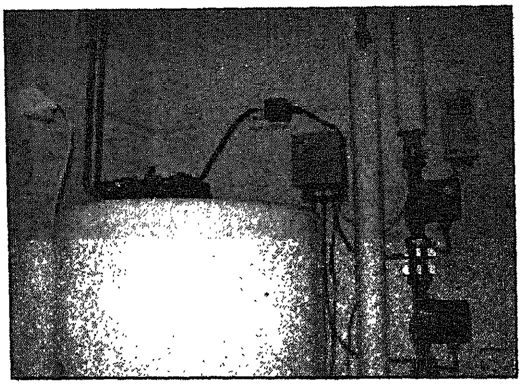


Figure 2 Heater tank supplying the laboratory wing with hot water. Tubes to and from the heat exchangers, with pumps and control unit are seen on the right. Grid electrical connection to the left is used in periods of low solar energy or high consumption

Vertical wind turbine

A 1.5 kW Darreius wind turbine was designed and built by a graduate student (Figure 3). The turbine was placed on the roof of our department, not the best place for energy production, but certainly the best place for promotion. Through both the students and the media, the turbine has become widely known throughout Norway.

Another student has collected all available information on small-scale vertical wind turbines by searching the Internet and other literature. Conclusions from this report will lead to the construction of a larger turbine which will be investigated as part of the student's masters degree. The bigger turbine will be connected to a newly invented low speed generator.

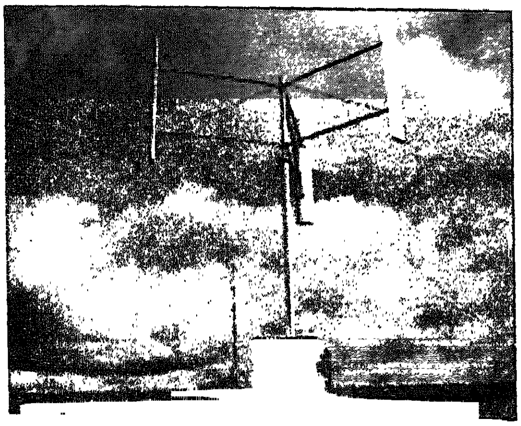


Figure 3 A Darreius wind turbine on the institute roof

The generator develops 1.5 kW at 300 rpm (revolution per minute) and will be directly connected to the turbine shaft, simplifying the micro wind power plant substantially.

Combined heat and power from biomass

A new combustion system for biomass was designed and built by a graduate student in the spring of 1998. The oven (Figure 4) can burn biofuels without any pre-processing, such as grinding, cutting, or chipping[1]. The fuel may contain nails, metal pieces, stones, and sand but will not cause any problems. The system accepts fuels with humidity up to 60%. The power output is 30–300 kW. Another student has designed and built a Tesla turbine for the production of electrical power from the biomass heat. A third student has designed and built a hot air engine in cooperation with our workshop. It can be described as a turbine where the compressor and the expander are replaced by pistons. The inspiration for its development comes from the Stirling engine. The result is a heat engine demonstrating well-defined and pure thermodynamic problems suitable for basic understanding. Another student is designing a mathematical model of the combustion process to develop a control system for the oven. One student has designed a system for the precise control of air supply to the oven, while another is running tests on several fuel types.

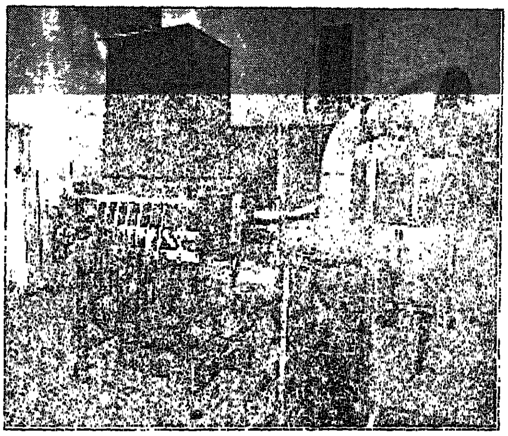


Figure 4 The multi-fuel oven; height: 2.4 metres

All the projects demonstrate the need for education on basic thermodynamics, physics, instrumentation, control system design, data acquisition systems, and result presentation.

---

[1] Homepage for multi-fuel oven:http://www.nlh.no/home/itf/itfphh/index.htm

The bioenergy activities have resulted in enormous interest from other students, teachers, farmers, industry, and the media. Two students have been employed by Organic Power, a company created to industrialize the new solutions. A 240 m^2 bioenergy laboratory will be built during the next year and several students will work on instrumentation, control, equipment design, and tests.

Solar sausage kitchen

A solar cooker and a refrigerator supplied with electricity from the PV panels constitute our solar sausage kitchen. An additional solar sausage grill is planned. From the solar kitchen, our students can serve hot dogs and chilled soft drinks to visitors; an effective PR gimmick.

The solar cooker has turned out to be the most convincing demonstration of the power of solar energy for our students, as well as the visiting guests. Boiling food is a familiar activity to everybody. When they see the filled 12-litre pan and feel its temperature, they relate it to their own experiences.

Data collection, control, and presentation

LabView has been chosen as the platform for data collection in laboratory work, system development, process identification, control and display, and data analysis and presentation. A basic course is given at an early stage and the students develop their skills during later problem solving. Several students will later encounter LabView again in industry.

Further plans

During 1999-2000, instrumentation and data acquisition and presentation will be the main activities. There is no funding available at the moment, but the necessary loggers, computers, and software are already available. Activities will continue as the students contribute freely. The next stages planned at the demonstration site include an air-to-air heat pump for heating/cooling the laboratory wing, a fuel cell producing electric energy from hydrogen, and a Stirling pump based on the Fluidyne principle. A solar grill will also be installed for the solar sausage kitchen.

Conclusion

Working on these projects, the students have learned electromagnetism, mechanics, and thermodynamics as well as automatic data acquisition through a 'hands-on' approach to problem solving. The students are very enthusiastic about this method of doing physics laboratory work and are eager to continue and develop it further.

In 10 to 15 years, several of these students will have important positions in Norwegian industry and officialdom. They will probably also advise politicians on energy related questions. This is the most important aspect of solar energy education.

Annexure 1

Global solar irradiance in southern Norway

On a clear summer day in the southern part of Norway, the 1000 W/m^2 rule of thumb for a surface normal to the radiation applies well. Figure 1 shows the solar irradiance on a horizontal surface for Aas, Norway.

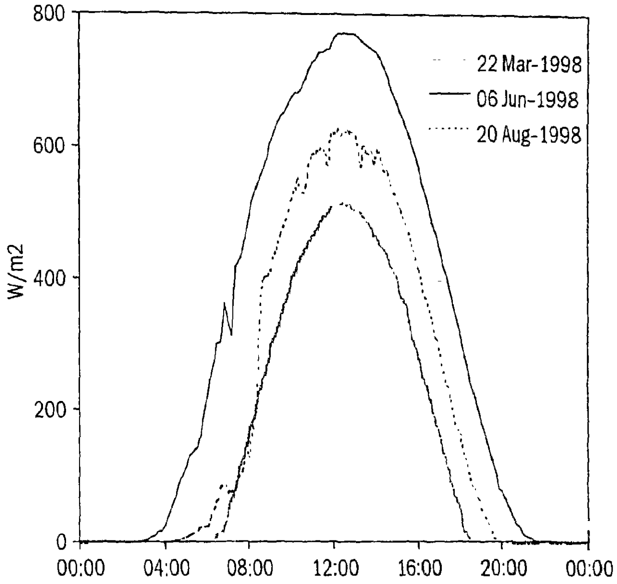


Figure 1 Global solar irradiance on a horizontal surface at Aas, Norway, on three clear days in 1998

Solar Research
Centre, EKOS,
Dalarna University,
SE 781 88
Borlänge,Sweden

Lars Broman*, Konard Blum, Vanni Garofoli, Lars Kristoferson,
Ulf Kusoffsky, Bengt Hidemark

Creating a European Solar Engineering School

Renewable energy education: current scenario and future projections
pp. 42-47

Abstract

A masters-level programme in solar energy engineering has been initiated. Students from the first programme will be admitted in the fall of 1999. A number of shorter masters-level courses are also planned. The first such course on advanced solar thermal engineering was held in the summer of 1998. This will be followed by several courses during the academic year 1999–2000. Discussions with the Italian Research Council regarding the future possibility of conducting courses in Anacapri, Italy, are in progress. A web site <www.eses.org>, has been created and is continuously updated.

---

*Author for correspondence

Introduction

Following the Brundtland Report (Agenda 21) prepared after the 1992 Rio Conference, and the 1997 EU (European Union) White Paper on RES (renewable energy sources) – Energy for the future: renewable sources of energy; White Paper for a Community Strategy and Action Plan; *http://europa.eu.int/en/comm/dg17/599fi_en.htm* – it is obvious that solar energy has to gradually replace non-renewable sources of energy. In this process, university-trained engineers play a crucial role. The engineering students of today are the designers of our technological world tomorrow. It is, therefore, necessary that these young women and men have a good understanding and comprehensive knowledge of renewable energy technologies.

In September 1996, the Solar Energy Research Centre, Dalarna University, Sweden, proposed that an ESES (European Solar Engineering School) should be created, where students from all over Europe could receive appropriate training. Such a school should be located somewhere in Europe where the climate was stable with clear skies during most of the year, so that laboratory work and hands-on experience could be regular part of the curriculum.

During the summer of 1998, a first trial course in advanced solar thermal engineering was conducted at Tingvalls Eko in south-west Sweden under the auspices of Högskolan Dalarna (the Dalarna University). In November 1998, a curriculum for a one-year masters-level programme on solar energy engineering was sanctioned by the university's educational board. This programme, as well as several shorter courses, are now scheduled for 1999 and 2000. Short descriptions of the programme and the courses is given below.

Masters-level programme in solar energy engineering

The one-year, full-time, masters-level programme in solar energy engineering was sanctioned by Högskolan Dalarna's Educational Board on 18 November 1998. The academic year was subdivided into four periods; thus the fall semester consists of Periods 1 and 2, and the spring semester consists of Periods 3 and 4. One full academic year of studies corresponds to 60 credits.

Aim of the programme

The programme will be a masters-level programme, building on the B. Sc. examination. Students will acquire knowledge in solar energy engineering in any four out of six specialities, namely advanced solar thermal engineering, advanced solar thermal engineering, continuation, advanced PV (photovoltaic) engineering; solar architecture/passive solar energy engineering; management and utilization of solar energy; and advanced solar energy engineering for tropical climates. After completing the course, students should be able to take charge of operations within the area of solar energy engineering. They will also have a sufficient background for being admitted to graduate schools within the area for further research. Courses can be studied separately as well.

Education During the courses (Table 1) the teaching method used will include lectures, problem-solving exercises, laboratory experiments, seminars, computer exercises, and study visits. The language will be English. Courses will be part-time (50%), in parallel with the thesis work. During the third and fourth periods, each student will have to chose two different courses.

Prerequisites A B. Sc. degree with a major in mathematics, science, engineering, or equivalent.

Thesis The programme includes the writing of a 30-credit masters-level thesis in solar energy engineering. The students would participate actively and under supervision in a research group. Halfway through the work, the results and plans for the continued work will be presented in writing and orally at a seminar. The final thesis will be presented in written form and defended at a seminar.

Diploma After successful completion of the course, the students will receive a Diploma in Environmental Engineering. Students who have the required background (in principle a B. Sc.) in mechanical engineering will become Masters of Science in mechanical engineering.

Table 1 Summary of the courses

Course code	Course name	Credits	Subject	Period
MÖD008	Advanced solar energy engineering	7.5	E e[a]	1
MÖD006	Advanced solar thermal engineering, continuation	7.5	E e	4
MÖD003	Advanced PV engineering	7.5	E e	2
MÖD004	Solar architecture/passive solar energy engineering	7.5	E e	3
MÖD007	Management and utilization of solar energy	7.5	E e	4
MÖD005	Advanced solar energy engineering for tropical climates	7.5	E e	3
MÖD002	Thesis in solar energy engineering	30	E e	1-4

[a] Environmental engineering

Courses (1999-2000)

The following courses are planned for the academic year 1999–2000. Each course worth 7.5 credits can admit around 20 students in addition to the 12 programme students. Prerequisites are a B. Sc. with a major in mathematics, science, or engineering; or an equivalent background. While plans are to continue with the ESES courses in the following years, there may be some revisions of schedules and topics.

Tuition will be free, but students will have to cover costs for travel, accommodation, and textbooks. The regular application date for programmes and courses that start in the summer or the fall is 15 April and for courses that start in the winter or the spring is 15 October. More information on courses, applications, etc. is available at www.eses.com. Students from abroad are advised to contact Mr Jari Rusanen at the University's International Secretariat at jru@eses.org for advice.

Advanced solar thermal engineering (7.5 credits)

The aim of the course is to give students knowledge that qualifies them for industrial R&D work on solar collectors and solar heating systems, for designing solar thermal installations, and for similar tasks. The curriculum includes solar radiation, solar material, collectors, energy storage, solar thermal systems, basic computer simulations, and measurements and characterization. The course code is MÖD008. The next half-time course begins on 30 August 1999 and another one is planned to start from 17 January 2000.

Advanced solar thermal engineering, continuation (7.5 credits)

The aim is to give students extended knowledge on industrial R&D work on solar collectors and solar heating systems, for designing solar thermal installations, and for similar tasks, as well as preparing for research in the field. The curriculum includes advanced solar materials, concentrating collectors, energy storage, solar thermal systems including seasonal storage, advanced computer simulations, and measurements and characterization. An additional prerequisite is a pass-course MÖD008 or equivalent knowledge. The course code is MÖD006 and the first course will start on 20 March 2000.

Advanced photovoltaic engineering (7.5 credits)

The aim of this course is to give students knowledge that qualifies them for R&D in the PV industry (devices and modules) for designing grid-connected and stand-alone PV systems, and for similar tasks. The curriculum includes solar radiation, semiconductor materials, modules and panels, electrical energy storage, PV and hybrid systems, computer simulations, and measurements and characterization. The course code is MÖD003. The summer course started on 14 July 1999 at Tingvall's Eko, Sweden, which gets all the heat and electricity from renewables. The fall course will start on 1 November 1999.

Solar architecture/ passive solar engineering (7.5 credits)

The aim of course is to give students knowledge that qualifies them for planning and designing houses and urban areas that utilize passive solar energy techniques and designs. The curriculum includes solar radiation, construction materials, passive solar designs, solar collectors and PV panels, computer simulations, and measurements in models and in full scale. The course code is MÖD004. The first course is scheduled to start on 17 January 2000.

Management and utilization (7.5 credits)

Here students will be trained to work in the fields of solar thermal and PV system assessment, management, and planning, both in governmental and local administrations as well as in utilities and companies. The curriculum includes a solar energy overview, political, managerial, economic, and cultural aspects on solar energy installations and EU and national laws relevant to solar energy topics. The course code is MÖD007 and the first course is planned to start on 20 March 2000.

Advanced solar engineering for tropical climates (7.5 credits)

This course will qualify the student's knowledge for R&D in solar energy export industries aiming at markets in tropical countries for working with solar energy. The curriculum includes solar radiation, solar heating and cooling, PV and hybrid systems, solar drying, distillation and other techniques, computer modelling, and design and measurements. The course code is MÖD005 and the first course is planned to start on 17 January 2000.

Thesis in solar energy engineering (30 credits)

Students working on the programme will spend half of their time during one full academic year working solar energy R&D. The aim of this course is to give students experience of working with R&D in a group together with solar energy researchers. The curriculum includes research methods, planning, executing, and reporting an R&D project, experimental and theoretical investigations, and writing and defending a masters-level thesis. The course code is MÖD002 and the first course starts on 30 August 1999.

Future plans

The ESES starts at Högskolan Dalarna, but alternative sites are being considered. One very suitable location is the former Swedish Solar Observatory in Anacapri, Capri, Italy (the Casa Solare). The site was abandoned in 1978, when the observatory moved to other premises, and was sold by the Swedish Academy of Science to the CNR (Italian Research Council).

There exists a tradition of solar-related science teaching and Swedish presence in Anacapri since the days when Axel Munthe created the world famous Villa San Michele. The site and the climate are also excellent for work on solar energy.

Discussions with the CNR are in progress regarding the possibility of providing ESES courses at the Casa Solare. The buildings at the site in Anacapri need major repairs, but the site is very interesting historically. It should be noted that a solar heating system with 30-m^2 solar collectors connected to a 3000-litre storage tank has been installed at the site as early as 1960/61. It is proposed that this system should be restored using modern components. The CNR's present plans are to restore the site so that it can be used in 2001.

Centre for Renewable Energy and Environment Development, Birla Institute of Technology and Science, Pilani - 333 031, India

M Ramachandran

Design and teaching of a course on renewable energy at Birla Institute of Technology and Science, Pilani

Renewable energy education: current scenario and future projections
pp. 48-57

Abstract

This paper is a case study of the author's experience in designing and teaching a course on renewable energy in the BITS (Birla Institute of Technology and Science), Pilani for the first time in August 1997, during the first semester of 1997–98. The design involved preparation of course curriculum, scope of the course, time frame for each topic, selection of text and reference books, and decisions about the teaching mode, design of student projects, evaluation methodology, etc. The subject was introduced as an elective for both graduate and post graduate students. The course has gradually gained acceptance by the students as reflected in the increasing number of students registering for the same, in every new semester. The paper describes the initial problems, the solutions devised, their results, current problems and the envisaged plan of action for the future.

Introduction

The Birla Institute of Technology and Science (BITS), Pilani is an all-India institute for higher education, deemed to be a University by the Government of India since 1964. It is privately supported, fully residential, and admits both male and female students.

BITS has adopted the semester system, modular structure of courses, continuous and internal evaluation, and letter grading. It has created linkages with industries, and over a period of time, developed several flexible educational programmes. Through its Practice School Programme, BITS has institutionalized the efforts to create purposeful linkages between the professional and the educational world. The institute operates at three tiers of education, namely, the integrated first degree programmes, higher degree programmes, and the doctoral programmes. All programmes contain certain structural commonalities and the common courses are invariably operated together. The various structural flexibilities provide scope for multiple-point entries. Electives are flexibilities allowed for students to choose to complement their compulsory disciplinary courses in order to either satisfy their urge for knowledge in the chosen course or to widen the scope and choice of their professional careers.

The author joined BITS as a professor in April 1997, after three decades of service of the Government of India. Out of these, for two decades, he was connected to the field of RE (renewable energy) in different capacities.

Course selection

The author was given the option of choosing a subject to teach in the semester starting August 1997, the first semester of the academic year 1997–98. The author chose to teach renewable energy for the following specific reasons.

- He had carried out his doctoral research from the Indian Institute of Science, Bangalore, in the field of RE, and
- The two decades of association with the subject in his professional career would help him be innovative, both in his approach to teaching and in designing the course content.

Once the subject was decided, the next decision was regarding the aspects to be taught. Should this be confined to any one area of renewable energy such as solar energy, wind energy, bioenergy, etc., or should the scope be enlarged to include all facets of RE? Should it be a lab-based course or a lecture-based course? After weighing all the considerations it was decided to teach an overview course on RE for the following reasons.

- Since the course is an elective, students of pre-final and final semesters of graduate and postgraduate degrees, who usually take electives, can avail of the same. These students would prefer to have an overall concept of the entire subject of RE, rather than intensively study any one area in the very first exposure to the subject.
- Since a large number of students invariably opt for professional employment soon after their graduation, it will be in their interest to have an overall idea of the subject so as to appreciate its relevance in their chosen profession.
- Several students also opt for higher education abroad soon after graduation, and an appreciation course on RE will enable them to join suitable programmes in the areas of environment protection, energy alternatives, pollution control, etc.
- The course could mostly be lecture-based at this juncture as suitable lab facilities in RES (renewable energy systems), in a comprehensive and integrated manner, are yet to be set up in BITS. In fact, for attending to this and other related objectives, CREED (Centre for Renewable Energy and Environment Development) was set up in August 1997, with the author as coordinator. The author wanted the course on RE to act as a catalyst for initiating projects for setting up a system design, development, testing, and training centre for RES and products. All these, in course of time, will result in quality degree programmes in various sectors and areas of RE in BITS.

ourse design nd structure

In BITS, the duration of any semester is four-and-a-half months and the available hours for teaching are about 40. Hence, the course had to be suitably designed and structured to incorporate all the envisaged components and be amenable to being completed within the stipulated period. This is normally a routine task with all courses, but in the case of RE, the task became complicated due to its wide scope. However, keeping the basic aims of the course in mind, the author structured the course, indicated in the 'course handout' described in a subsequent section of this paper.

Selection of textbook

The selection of the course was based on certain considerations enumerated earlier and not on any available book. The course was being developed for the first time in BITS, the selection of a suitable textbook posed some problems. No book exists, to the best of the author's knowledge, which comprehensively covers all the planned topics. To prepare a textbook within a short notice is not in the realm of reality. Hence the author had to strike a compromise and select one textbook and two reference books to cover all the technical aspects of his course and rely on other sources such as conference papers, journals, and his own records. Details of the course plan, textbook and reference books prescribed, and other aspects are indicated in the 'course handout' explained below.

Course handout

A document incorporating a brief synopsis of the course, the selected text and reference books, topics proposed to be covered, the planning of the lecture hours for teaching the topics, the evaluation methodology for the course during the semester, and the chamber consultation hours for visiting the teacher concerned is designed by the instructor-in-charge, printed by the Dean Instruction Division, and handed over to the students in the very first lecture hour of the course by the instructor concerned. The student is in a better position to understand the course load, requirements for evaluation etc. An instructor is expected to strictly adhere to the plan of action designed by himself. A reproduction of the current semester's course handout is shown in Box 1.

While dealing with topics concerning strategies for changeover to RE sources for power generation, the author stresses to the students that the gradual escape from the problems of conventional energy sources in the industrialized sector is through the route of energy conservation, end-use efficiency, and finally, adoption of renewable energy. Stress is also laid upon to the need to strengthen the commercialization base of RE sources against competition from conventional energy gadgets or equipment to enable them to be preferred by customers, so that their survival is not dependent on government subsidy but the strength of their own markets.

Teaching methodology

In view of the special nature and scope of the course, the author has adopted the following teaching methodologies.

Transparencies

Lectures through transparencies are adopted for the following reasons.

- Time spent on writing on the blackboard is saved for more explanations.
- Face-to-face contact with students while teaching ensures greater rapport and assessment of their reaction.
- Time spent in the preparation of the transparencies ensures apt selection of points to be highlighted in the

ERGY RESEARCH IN

Box 1 The course handout

Birla Institute of Technology and Science, Pilani
Instruction Division
First Semester 1998-99
Course Handout (Part II)

02/08/98

In addition to part-I (General Handout for all courses appended to the time table), this portion gives further specific details regarding the course.

Course No. : BITS C462
Course Title : Renewable Energy
Instructor-in-charge : M Ramachandran

1. *Scope and objective of the course*
   Introduction to renewable energy sources, broad details of technology of utilization of different RES, techno-economic analysis of energy generation by different RES, policy issues governing RES development in India, and factors governing commercialization of RES.
2. *a) Text book*
   Johansson, Thomas B, et al. Island Press, 1993. *Renewable Energy Sources for Fuels and Electricity.*
   b) Reference books
   - i) Bansal, Narendra K. PHI, 1990. *Renewable Energy Sources and Conversion Technologies.*
   - ii) V V N Kishore, TERI, 1993. *Renewable Energy Utilization-Scope, Economics, and Perspective.*
3. *Broad course plan*

Topic of lecture	Lecture hours
1. Introduction, potential, advantages, and scope for utilization of RES	4
2. Lectures on individual RES, their technologies, application areas, and status of development covering: i) solar energy ii) wind energy iii) bioenergy iv) micro-hydel, and v) other RES such as geothermal, ocean energy systems, solar hydrogen, fuel cell, MSW, and hybrid systems	28
3. Techno-economic analysis of RE power generation	2
4. Policy framework for RE development in India, and policies of Central and State governments for RE development	4
5. Status, opportunities, challenges, and tasks for commercialization of RES in India	2

Note The course handout also contains information on the evaluation plan for the course, the chamber consulting hours, and the noticeboard for course notices.

topic, though this necessitates extra effort from the author.

- Undue reliance on teacher's memory is avoided as the teacher is required to use his acumen to explain the topics rather than remember the lecture notes or points, especially in a descriptive course.
- Transparencies become permanent records for reference for both the teacher and the taught.
- For subsequent semesters, the transparencies can be suitably updated. Additional transparencies can be added to cover more information or a few transparencies removed if found outdated.
- Planning for the lecture daily becomes highly disciplined with the help of transparencies. We can decide to cover a pre-selected number of transparencies, thus meeting quantitative as well as qualitative requirements of teaching during the specified time.

Video films The author decided to supplement lecture hours with the exhibition of a few video films on RE sectors. The main reason for including the video film exhibition in the course is to enable the students to see the concepts of RE technology and utilization taught in the classes being adopted in industries across the country.

After each video film, the students are required to submit a short summary of the highlights to be evaluated. This is to ensure that the purpose of the exhibition of the video film is not defeated, and greater attention is rewarded.

Practical emonstrations In order to make the teaching process more convincing, based on the axiom 'seeing is believing', exhibits of SPV (solar photovoltaic) gadgets such as lanterns, cells, panels, fans, etc., and solar thermal equipment such as solar box-type cooker are displayed in working conditions to students. These gadgets are connected to electrical instruments and gauges to demonstrate the solar voltage and current being generated/consumed. The principles of operation and actual functioning of RE instruments such as solar pyranometer, half-cup anemometer, etc., are demonstrated to strengthen their theory.

Seminars The fourth method for incorporating knowledge is to allow the students to select any one of the topics of the course in the beginning of the course and prepare to make a presentation in a seminar after a stipulated period, mutually agreed between the teacher and students. The students are informed of the aspects of evaluation in advance. These include:

- literature survey done, and depth of study, as reflected in the contents of the seminar address, and
- skills of presentation facing queries from the audience, which will include other students and the teacher, apart from invitees.

These seminars form important components of academic evaluation of students to inject seriousness in the preparation.

Home assignments

These assignments are specifically oriented to increase the students' awareness levels about RE. These can be the study of literature and journals on renewable energy and submitting a report on an assigned topic, or submitting an inspection report after visiting existing RES on campus such as solar hot water systems, or a biogas plant. The latter includes sketching the system, finding its performance levels, and analysing the reasons for the same. These reports are considered as components for students' evaluation and given suitable weightage.

Feedback from students

Periodic feedback is sought from the students for understanding their reactions to the teaching methodology. By incorporating the useful suggestions, the chosen methodology can be modified to suit the requirements and expectations of the students, who, after all, are the final beneficiaries (or victims!) of the chosen process of teaching.

The feedback has indeed helped the author to understand students' needs and psychology better and make the topics more interesting, so much so that it has been made a regular feature of the author's teaching system. The author has also learnt that students relish real-life facts from his professional career for highlighting an aspect rather than merely quoting from a book. The students confirmed in their feedback the greater efficacy of transparencies and video films in conveying concepts. Based on the feedback, a few topics have been added and a few others further elaborated.

Student projects

These are important aspects of a student's curriculum in BITS. Each student is required to do at least one project during the graduation career. These projects can be study-based, lab-based, or computer-based depending upon the nature. Students have the freedom to select any topic and faculty as the guide for the project.

In the author's semester of teaching, the practical problems of identifying projects emerged. There was no laboratory for lab-based projects. The course was too new to attempt computer-based projects. Hence the choice was between on study-based projects and field-based projects. Some of the projects undertaken by the students under the author's guidance are detailed below.

The study-based projects included studies on wind energy development status in the world, bioenergy projects in India, and solar thermal utilization status. These projects turned out to be very useful reference bases for subsequent students wanting a basic overview of the topic and a ready list of literature available in BITS on the subject.

One project was conceived on analysing the scaling problems of BITS solar hot water systems, a field-study-oriented project, whose results enabled better understanding of the problem.

Similarly, a student was encouraged to undertake a project to evaluate the potential for garbage utilization within BITS campus which has 400 households where all the staff and faculty of both BITS and Birla Education Trust Schools reside. Garbage from households, institutions, shops, etc., was collected over three days by the student with the help of NSS volunteers and sweepers. After analysing it, the student arrived at information concerning the quantum of recyclable, compostable, and disposable waste per annum. This project report has become an invaluable document for future reference, in case any feasible project proposal for the actual utilization of campus waste is taken up for implementation.

A student completed a project in which theoretical and practical lessons for teaching the basic concepts of SPV energy systems, their operation, and maintenance were prepared for training technicians. Apart from preparing demonstrative SPV circuits, the student prepared elaborate charts to explain the theory and practicals of SPV circuitry.

Recently a project was sanctioned by the MNES (Ministry of Non-conventional Energy Sources) for installation, commissioning, and performance evaluation of parabolic solar cookers. This has generated useful and challenging project concepts for RE students. Two students are at present involved in the same. After the completion of their semester, two other students will continue the work till the completion of the evaluation duration specified by MNES. So far, the project has yielded valuable data.

A symmetrical, twin-basin, conventional solar still, of concrete-masonry type and 100 litres capacity, was set up in BITS during the last semester, under the supervision of the author. The still meets the entire distilled water requirement of the various labs of BITS. In the current semester, the still has attracted two students of RE course for undertaking viable projects. They are currently evaluating the performance of the still with respect to solar insolation and other aspects.

Two students are working on the collection of useful information from the Internet for dissemination to students. This includes areas of RE subject such as foreign universities offering post graduation, doctoral courses in RE or related subjects, job opportunities in firms specialized in or dealing with RE subjects, etc. These weekly reports are disseminated amongst students to increase their awareness levels about all aspects of RE. This has helped students appreciate the relevance of RE not only as an energy alternative but also as a career prospect.

Apogee exhibits

During every second semester of the academic year, students of various groups and disciplines organize a technical exhibition of gadgets and models fabricated by them, which depict innovative ideas and concepts. This exhibition is known as *Apogee*. The quality of the exhibits is usually very high. Judges, consisting of faculty of BITS, inspect and choose the best exhibits for awards. In the *Apogee* of March 1998, students of RE course from two different disciplines exhibited non-working models of RE systems. One exhibit displayed the concept of RES for environment protection and the other exhibit depicted RES for energy conservation. Both exhibits were admired, and created greater awareness regarding RES amongst all the students and faculty.

Future plans

Throughout the year, hundreds of tourists daily visit the excellently maintained Birla Museum, marble temple of Goddess Saraswati, and other places of interest within BITS campus. These tourists mostly belong to rural places in Jhunjhunu district and other surrounding districts of Rajasthan which are drought-prone and starved of fuel sources. Hence it is proposed to set up a RE park, in which all the RE systems will be displayed in working condition. The tourists will be immensely benefited by visiting the proposed Energy Park as they will gain awareness on the possibilities of utilization of RES in their houses and community and the disadvantages of using conventional energy systems. The RE Park will enable RE course and project students to have greater scope for the study of design, development, and application of RE utilization systems, tailored to the needs of rural people.

In collaboration with the Centre for Electro-Chemical and Electrical Research, SPIC Science Research Foundation, Chennai, CREED has embarked upon setting up a facility for the study of fuel cells in BITS. One SPEFC fuel cell was set up in October 1998 and student projects are on. After completion of the same, the facility will trigger off several research projects at different levels, on the various aspects of fuel cells.

It is well known that the Internet is gaining importance in academic institutions, like elsewhere, as the information highway across the world. Visiting important web sites, relevant to their courses and career, is gaining popularity with students, apart from its use for transmitting e-mails. Taking advantage of both these aspects, the author is designing, for the ensuing semester, study-based projects for students, whose reports will contain mainly the information gathered from the Internet on the topic of their projects, which will be collected, correlated, edited, and assembled as a report. This will also help to update the knowledge base of the topics of lectures.

Conclusion

The response of the students for the RE course and projects has been very encouraging. In the first semester of offering the new course in RE as an elective, eight students registered, from disciplines like mechanical engineering, chemical engineering, and civil engineering. In its second semester, 21 students opted for the course as their elective, from the above disciplines. In the current semester, 29 students from six disciplines have registered.

Similarly, the number of students opting for projects in RE subjects has steadily increased from four in the first semester to nine in the current semester. This number would have been much more, but for the prevailing limitation, for the number of projects to be guided by a teacher in a semester. Fourteen students have already reserved, informally, projects in RE subjects under the author's guidance for the next three semesters. Most of these students have completed the RE course under the author. This response has given ample proof to the author about the growing popularity of RE as an elective course amongst the students of BITS, and confidence about the teaching methodology adopted so far. The author hopes that this response will result in dedicated degree programmes in RE subjects at BITS, in the near future.

Acknowledgement

The author gratefully acknowledges the constant guidance and encouragement received from Dr S Venkateswaran, Director, BITS, Pilani but for which the progress made so far in teaching RE course would not have been possible. The author is also indebted to Prof. K E Raman, for his support and help.

TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi -
110 003
India

Anitha Saravanan

Designing packages for renewable energy education

Renewable energy education: current scenario and future projections
pp. 58-68

Abstract

Energy consumption is increasing exponentially in all the countries. It has been observed that the energy consumption in the developed countries doubles every 10–15 years, every 7–10 years in the developing countries, and every 5–10 years in the underdeveloped countries. As a result, our natural resources are depleting rapidly. The inefficient use of energy in poorly conceived projects has also contributed its shortfall. To meet the increasing demand for energy, alternative energy resources need to be explored along with conserving existing resources. EE (energy education) can play an important role in creating awareness of environment-friendly industrial development, and in achieving a sound economy. It has thus become essential to educate the public, schoolchildren, educators, planners, policy makers, and decision makers on the present energy scenario and the need to conserve energy.

This paper highlights the need for (1) relevant educational packages in imparting EE in a typical Indian scenario, (2) a teacher's role in imparting EE, and (3) improvement in the current TLS (teaching-learning strategies). An attempt has been made to design an educational package for solar heating systems as a teaching aid for senior secondary school students. The paper also lays emphasis on the use of combined TLS to bring out the desired effect keeping in view the subject matter and its implementation.

Energy education

EE, as the term implies, should enable people to perceive energy in its totality, i.e., totality of physical, biological, socio-economic, and cultural complex. EE programmes should arouse awareness, sensitivity, and provide perspectives of energy-related problems to motivate students to get involved in energy action programmes at the school level (George 1990). These students could later influence policy framing in the long run. EE should be problem-centred, interdisciplinary in nature, value- and community-oriented, and concerned with man's harmonic survival as a species. It should be based on students' initiatives, activities, and involvement, and must be present- and future-oriented. Finally, EE should provide solutions to the energy crisis, expose present-day children to renewable energy sources, and prepare them to meet future demand through alternative and new renewable energy sources (Garg, Kandpal 1996). In India, the following aspects need to be emphasized while designing EE modules for senior secondary school students.

- Energy scenario: local or regional, national, and global; its crucial and dominant role in both economic development and social transformation
- Energy resources and their classification into renewable and non-renewable
- Consumption patterns in different sectors: household, agriculture, industry, transport, communication, and other sectors at the national and international level; demand–supply gap
- Environmental conservation and problems associated with energy consumption: energy consumption and environmental pollution; industrialization, urbanization, and energy problems; environmental pollution and public health; and nuclear energy and environmental problems
- Conservation of energy resources: use of domestic wastes; energy audit, saving energy; concept of reduce, reuse, and recycle; improved technologies of energy consumption, their production, and practical implementation, e.g., solar cooker, improved cookstoves, biogas, windmills, and solar heating systems
- Current storage of energy during off-peak hours and emerging technologies to generate new forms of energy
- Environmental degradation (due to energy production and utilization), environmental management, and sustainable livelihood: primary and secondary pollutants, depletion of ozone layer, global warming, biological damage, industrial pollution, and environmental impact assessment.

The main objective of EE is to develop scientific and social attitudes for the senior secondary school children. The teacher is the most important person in implementing EE in schools.

Role of the teacher

The process of education depends on many factors: sound curricula, appropriate textbooks, functional audio-visual aids, infrastructure, etc. Most important of all, it depends on the people who, with their talent and competence, interpret the curricula and achieve objectives. The teacher aids the students in understanding the subject, developing skills and attitudes. Thus, imparting training to teachers is one of the most significant aspects in the development of EE programmes.

There is a lack of trained personnel in the field of EE in India. The senior secondary school teachers teaching various subjects must be trained to understand and appreciate the interdisciplinary nature of environmental issues associated with energy production and usage. The training would enable them to use and evaluate pedagogic methods to understand the receptivity of the students.

For EE to be successful, open-minded and competent teachers with a clean understanding of environmental management concepts will be required. This will require (1) the selection and training of teachers within existing staff; (2) ecological-environmental studies as a fundamental subject in the training of all teachers, whatever their specific fields; (3) continued in-service supplementary courses for teachers; and (4) the preparation of a core of teachers in ecology and environmental science to provide leadership in this field. While undergoing training, teachers should study the relationship between man and environment at their own level of inquiry, and explore the contributions which their subjects can make in the field. In-service training should also include members of the school council, supervisors, and administrators.

Energy education for senior secondary school students

Energy education for schoolchildren could begin at the primary level, which will lead to creating awareness on energy sources and conservation aspects. At the secondary and senior secondary school levels, the basic skills for tackling and solving energy problems are developed. The following reasons make senior secondary school students suitable for EE.

- Some of the senior secondary school students will pursue higher education for specialization in various fields.
- At this level, students would have the opportunity to apply energy-efficiency concepts at school and at home. Also, this is the time when students get involved in out-of-school activities, which include problem-solving and community action.

- Students will be able to see clearly why they should be concerned about the environment. They will be able to relate to real-life experiences, and understand how these problems affect our day-to-day lives.
- They would be able to organize and implement action-oriented energy-efficiency programmes at the school level to bring about a change.
- It would also help eradicate individualistic scale of values and foster development of values based on the interest of the society (Eichler 1997).

Teaching–learning strategies

A teacher plays an effective role in implementing any educational programme successfully and effectively. It is the teacher who uses educational aids/materials, creates a learning atmosphere in the classroom/outdoors, motivates students, and achieves objectives. Thus, a teacher should be well-equipped with principles, methodologies, skills, modern innovations, techniques, and on the whole, state-of-the-art TLS.

TLS provide experience or situations for imparting desirable knowledge, skills, and techniques. Selecting appropriate TLS by the teacher would help in achieving the set objectives. There is thus an urgent need to devise and stabilize effective and suitable TLS. As EE is an interdisciplinary subject, different strategies must be combined to achieve the desired results keeping in view the subject matter and its practical implementation. The selection of a strategy should be based on the awareness of the teacher; teacher's personal knowledge, experience, and skill; teaching–learning situation; background of the learner; and availability of resources.

Some of the methodologies that could be adopted for school students are area-wise monitoring, brainstorming sessions, camps, charts, community action programmes, computer programmes, debates, developing reports, discovery, educational trips, energy clubs, exhibitions, experiments, games, group discussions, interviews, lectures, media, models, projects, puppet shows, role plays, simulations, surveys, symposia, theme festivals, use of expert's knowledge, video films, site visits, and workshops.

A combined strategy using the methodologies listed above could be adopted to get the desired effect. A minimum of one strategy and a maximum of three strategies is ideal for a teaching–learning situation. Since India is a vast country with varied climate the teacher imparting EE must select and develop methodologies that suit the school environment. Some combinations are suggested below.

1. Project + presentation + discussion
2. Lecture + chart + demonstration
3. Field trip + demonstration + discovery approach
4. Lecture + audio-visual + living organisms
5. Computer-assisted programmes + learning + self study
6. Interview with experts + report + presentation/discussion

The teacher could also initiate discussions on the strategy to sum up learnings and to link the various topics under discussion.

Designing educational packages

An educational package would be effective in a teaching–learning situation. As the objective is to inculcate scientific and social attitudes among senior secondary school students in the long run, the educational package should be designed to include current problems as well as ways and means of developing instrumental and problem-solving skills. The package design should be based on scientific knowledge combining natural, physical, and social environment. The contents, concepts, and the mode of treatment of contents should be unique to each state or region or country. The curriculum at the school/regional level should be based on the social and cultural needs of the region to provide an adequate and appropriate place for practical work and co-curricular activities.

A structural method of developing an educational package with the subject content for solar heating for homes has been worked out for a typical Indian situation in this presentation. Ideally, a teacher is the best person to adopt various methodologies which would best suit the subject. An educational package should have the following elements.

- *Concept base*: to give the basic concepts on that particular topic and to outline the contents
- *Development of educational material*: data collection and compilation based on the developed concepts
- *Activities*: targeted at particulars age groups, based on the educational material
- *Feedback and evaluation*: based on the activities conducted, the feedback from the students is assessed and evaluated by the teachers to assess the students' learning
- *Action*: based on the feedback and evaluation, the teacher could further develop on the topic as indicated. In the case of students, some of the approaches or methodologies followed may lead to action, change in attitudes or lifestyles

Educational package for solar heating

A combined strategy has been used to explain solar heating where the students not only learn and understand but also try to implement and find many applications of solar energy.

Concept base Developing the concept is basically the job of a teacher. The teacher collects background information to develop concepts on solar energy; its availability as a renewable source of energy in India, especially at the state level; and application of solar energy in various fields in different states of India, specifically solar heating.

Development of educational material Based on the data collected, the teacher could devise methodologies for teaching various topics. The teacher could identify case studies suited to their region and explain the concepts. For example, states such as Gujarat, Rajasthan, and Andhra Pradesh have high potential for tapping solar energy, thus enabling these states to use solar operating devices. A detailed outline of the topic could be developed at this stage by the teacher.

Activities The development of activities for children is a very important task. One needs to keep in mind the learning processes of children while developing activities. Since a combined strategy has been used, an attempt has been made to explain the methodologies in detail and as to what should be taught using a particular methodology.

Lecture The teachers could brief the student on solar energy and how it can be captured for electricity and lighting for residential and commercial purposes (in this case, it could be a solar collector) in various states in India. Case studies could be given. Solar heating and its application can be explained. Solar collectors and their structure can be explained with the help of visuals. Real-life examples and traditional methods of conservation could be discussed.

Visit A field visit could be arranged by the teacher either to a user, or a manufacturer, or an R&D institute in a village, town or city. Such visits would enable the students to understand the principle, functions of the components, and the method of operation of any solar operating device available at that place (solar cooker, solar lighting, solar heating, solar cooling, etc.). It would also help the students understand the mechanics involved and the economic aspects of using a solar energy operated device. This would initiate learning and exploring other options of capturing solar energy for homes.

Model making

The construction of a solar collector has been explained in this paper. Teachers could guide the students in making a solar collector. By this method, students would understand the preliminary design and the exact functioning of a solar air heater (see Figure 1). This would facilitate thinking on various new technologies and options. Here, the economics of solar heating and electric heating may be compared. Energy audit sheets for solar air heaters can be worked out and the economics of developing and using solar air heaters can be studied.

Discussion on active solar air heating

The benefits of using solar heaters and energy saving could be discussed. The amount of energy conserved compared to that of electric heating systems can be calculated on an annual basis in a particular region and alternative methods of capturing energy can be thought of. The advantages and the improvements in lifestyle using solar heaters can be discussed.

Making a solar collector using materials available locally

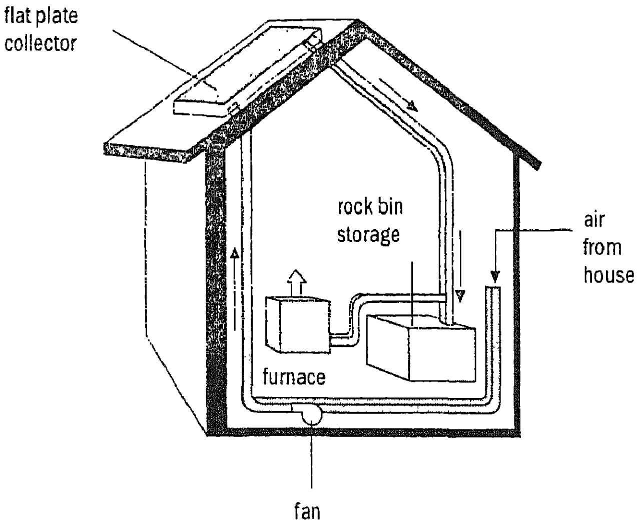


Figure 1 Solar collector

Objective

To understand the operating mechanism and the construction aspects of a solar air heater.

Material required

Cardboard, measuring tape, scissors, Plaster of Paris, black acrylic paint, paintbrush, thumbtacks, duct tape, thin string, plastic wrap, masking tape, thermometer, graph paper.

Method

1. Find a sun-facing window and note its measurement (height × width) (Figure 2a).
2. Cut a piece of cardboard of the same measurement (window size) with five-inch flaps extending on all the four sides (Figure 2b).

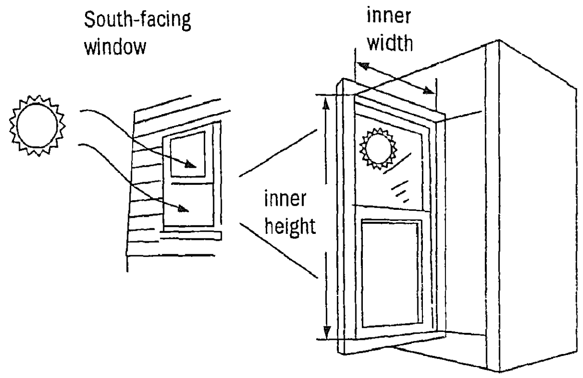


Figure 2a

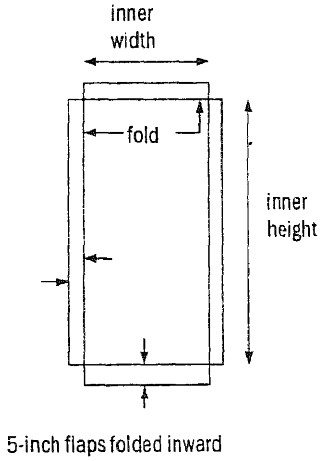


Figure 2b

3. Apply a coat of Plaster of Paris on one side and allow it to dry for 10 minutes (Figure 2c).
4. After the paste has dried, paint the same side of the cardboard with black acrylic paint. Allow it to dry (Figure 2d).

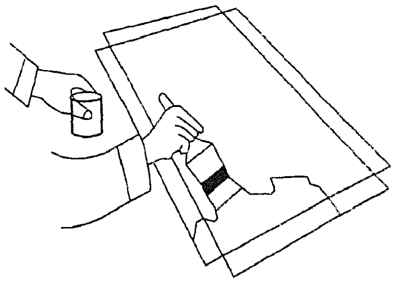


Figure 2c

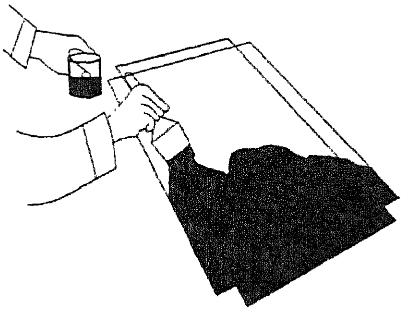


Figure 2d

5. Cut three vent holes of three inches × three inches near the top and bottom flaps (Figure 2e). (The number of vent holes can vary based on the size of the window.)
6. Push thumbtacks into the cardboard around the vent holes on the other side of the cardboard (not on the side where black paint is applied) (Figure 2f).

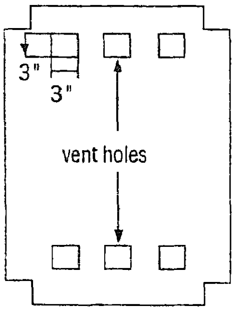


Figure 2e

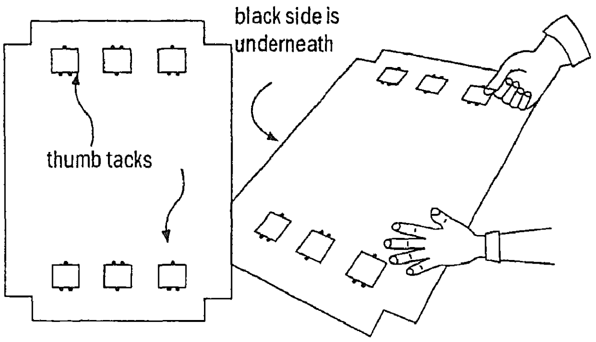


Figure 2f

7. Weave some thin strings around the thumbtacks and across the vent holes (Figure 2g).
8. Cover the thumbtacks with thin strips of duct tape to prevent them from falling out of the cardboard (Figure 2h).

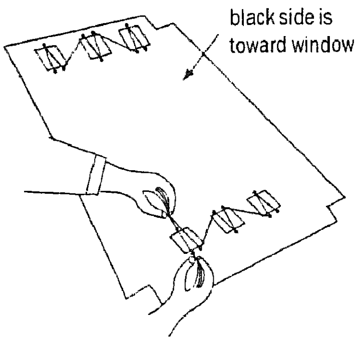

black side is toward window

Figure 2g

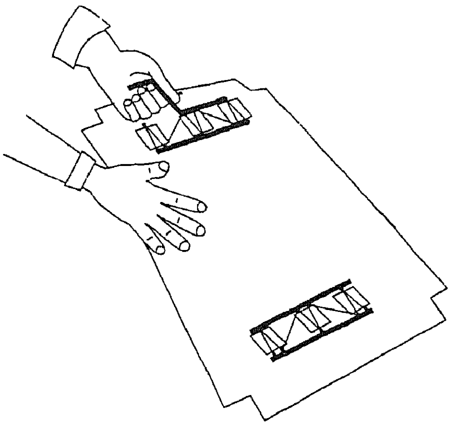


Figure 2h

9. Cut enough plastic wrap to cover the vent holes and tape the plastic to the outside (black side) of the bottom vent holes and to the inside (string side) of the top vent holes (Figure 2i).
10. Slide the cardboard inside the window frame with the black side facing the window and the top vent holes up. (The plastic flaps should be hanging over the vent holes.) Tape the cardboard to the window frame with masking tape and leave air space between the window and the cardboard (Figure 2j).

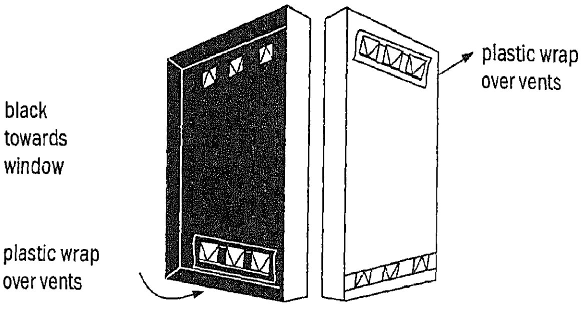


Figure 2i

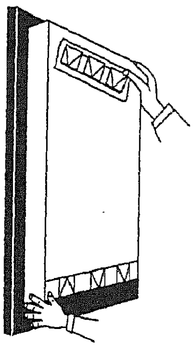


Figure 2j

11. On the graph paper, draw a table marking three columns and write 'time', 'intake temperature', and 'output temperature' at the top (Figure 2k). Note the temperature by holding the thermometer under the plastic flaps (Figure 2l) covering the vent holes for two minutes to measure the intake of collectors (bottom) and output (top) temperature. This can be done every few hours and on different days (cloudy, rainy, and sunny days).

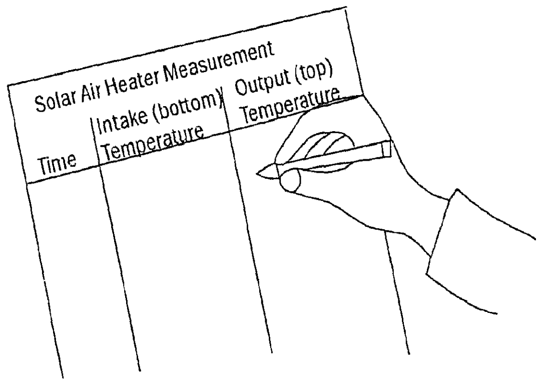


Figure 2k

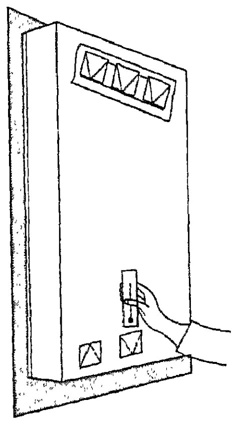


Figure 2l

Source for all figures: http://www.ereu.doc.gov/erec/factsheets/factsheets.html

One can see that most solar collectors are either boxes or frames which trap heat. This heat is collected by means of absorbers. Insulators are also part of the solar heating systems that prevent heat from escaping. The collected heat can be used to heat homes, water, and other applications. The same principle applies to a solar cooker used for cooking.

Feedback and evaluation

Evaluation is an integral part of the education process. The teacher needs to continuously evaluate the students' activities to find the level of understanding of each student. To test the students, the teacher could ask them to identify three energy-related problems in the school, their homes, or in their community, industry, etc. and devise methodologies to solve the problem. Similarly students could be asked to give feedback on the methods of teaching, facilities, and their learning levels. An analysis sheet should be designed, which could be referred to check learning of the students. Evaluation can also be done by the teacher at various stages – at the concept stage, at the stage of developing educational material, and while performing activities.

Action

Effective TLS would encourage students to implement energy-efficient technologies in their home, schools, or communities. Students would take measures to conserve energy. They could also develop an energy-efficiency programme for the school and consider aspects of saving energy and harnessing other sources of energy (solar, wind, etc.) for various purposes based on the resource availability, facilities, infrastructure, climatic conditions, and other factors. Students could think of various solar operating devices, their applicability, and implementation at various places right from home to society level.

References

Eichler A. 1997
Environmental education at the secondary school level
In *Trends in Environmental Education*. pp. 101–104
Paris: United Nations Educational Scientific and Cultural Programme.

Garg H P, Kandpal T C. 1996
Renewable Energy Engineering Education. pp. 72–83, 109
New Delhi: Omega Scientific Publishers.

George R. 1990
EE: a pressing need
In *Energy Education*, edited by Beena Shah
New Delhi: Northern Book Centre. 288 pp.

Bangladesh University of Engineering and Technology, Dhaka - 1000, Bangladesh

M A R Akhanda

Present status and future direction of renewable energy education in Bangladesh

Renewable energy education: current scenario and future projections
pp. 69-73

Abstract

This paper discusses the present position and future programmes of REE (renewable energy education) in Bangladesh. A number of teaching institutes like BUET (Bangladesh University of Engineering and Technology), BAU (Bangladesh Agricultural University), DU (University of Dhaka), IIT (Islamic Institute of Technology), and BIT (Bangladesh Institute of Technology) offer courses on solar energy, wind energy, and wave energy. Most of these courses are offered as selective courses in conventional engineering/applied science curricula. At school and college levels also some topics on renewable energy are offered. BUET, BAU, DU, IIT, and BITs also organize workshops, seminars, symposia, and conferences from time to time. The IEB (Institution of Engineers, Bangladesh) and the BSES (Bangladesh Solar Energy Society) also organize similar programmes. The BOU (Bangladesh Open University) offers some non-formal lectures on renewable energy by mass communication. The CES (Centre for Environmental Studies) of the BUET and DU are planning to introduce independent postgraduate programmes of one to two years on this in the near future.

Introduction

Bangladesh lies in south Asia, with the Bay of Bengal to its south. There is a good prospect of renewable energy (RE) in this country due to its location. Solar radiation over Bangladesh has been estimated to provide nearly 600 times the present energy consumption from traditional and commercial energy sources. The long-term wind data in the coastal areas in this country indicate that this is an opportunity for the application of windmills in those areas. Wave power can also be significantly used here as an alternative source of energy. A balanced and fast adoption of RETs (renewable energy technologies) in this country, therefore, need adequate and well-trained manpower. Therefore, education and training in RE (renewable energy) at all levels is of prime importance. All these have tempted many teaching institutes to offer a number of courses on RE at different levels.

Some researchers of the then Ahsanullah Energy College, Dhaka (which has become BUET, Dhaka since 1962) started developing the idea of renewable energy since the mid-1950s. They worked mainly on solar and wind energy. Since then some courses have been introduced at the postgraduate level.

Objectives

The main objectives of the RE courses are:

- to develop awareness among students about the importance of issues relating to energy (its nature, need, use, generation, etc.);
- to make the students aware of different types of renewable sources of energy, their resource potential, and existing and futuristic technologies to harness them;
- to make students appreciate various energy policies and their impacts; and
- to make students study several alternative strategies.

Classification

Energy education programmes can be categorized on the basis of:

- mode of education – formal and non-formal;
- type and level of students;
- geographical area covered; and
- duration – short term, long term, modular, etc.

Formal education is imparted in schools, colleges, institutions, and universities and is well planned over years and well structured with identified objectives and needs. The non-formal mode of education, on the other hand involves learning from mass communication media (TV, radio etc.).

Teaching programmes

The present position and future programmes of REE – formal and non-formal – in this country are summarized below.

University/ institute levels

There are nine state universities, four BITs, and one IIT in Bangladesh. Of these, BUET, BAU, DU, BIT Chittagong, BIT Khulna, and IIT have introduced a number of courses on renewable energy in their different departments at both undergraduate and postgraduate levels. All these courses are offered as selective courses in conventional engineering/ applied science curricula.

Courses offered at BUET are solar energy, RE, wind power, and wind turbines. Solar energy includes solar radiation, solar energy availability, flat-plate collectors, concentrators, solar pond and solar still, SPV (solar photovoltaic) systems, and thermal storage. RE includes solar energy, wind energy, biogas, and biomass. Wind power includes wind energy, wind site selection, characteristics, site surveying, drag and lift, wind machines, machine characteristics, system design for generation of electricity, and water pumping. Wind turbine includes classification, theory, aerodynamic design, vibration, and stress analysis.

Courses offered at DU are solar radiation, solar energy availability, flat-plate collectors, concentrating collector, solar cells, SPV energy convention, design of SPV systems, and RET. Courses offered in BITs are heat transfer and solar energy, and heat transfer includes solar radiation. Courses offered at BAU and IIT are heat transfer, solar energy, and RE.

Polytechnic level

There are 20 polytechnic institutes in Bangladesh. They offer three year diplomas in various engineering fields. The departments of power and electrical engineering offer courses on RE. This course of *Power Plant Operation Performance of Economy* as a selective course includes definition, collection system of solar energy, PV system, solar thermal power generation system, solar refrigeration, solar pond, and solar still.

School and college level

At this level, no formal course on RE has been offered. But the Textbook Board has published a number of books containing a description of the windmill and solar energy projects. The general science subject includes solar energy, biogas plants, windmills, and wave energy.

Non-formal education

The BOU offers some non-formal lectures on renewable energy over television from time to time.

The DU and BUET have energy parks in their campuses, which are used for demonstration purposes. A number of rigs on solar energy have been installed in the DU park. The BUET energy park has rigs on both solar and wind energies. These are the research projects/theses of undergraduate and postgraduate students of engineering. Most by the components of these rigs have been fabricated in BUET workshops.

The NAEM (National Academy for Education Management) is giving various trainings on education management to college teachers periodically. They offer a course on solar energy, which includes the definition of solar energy, collection systems, solar cooker, solar clock and watch, solar battery, solar refrigeration, solar water heater, PV system, etc.

Workshops/ seminars/ conferences

The BUET, BAU, DU, BAEC, and IEB organize workshops, seminars, and conferences from time to time on renewable energy/solar energy.

Recent activities are given below.

- CSE of BUET organized a workshop on renewable energy in 1996. This workshop included solar energy among other fields of renewable energy.
- The BSES arranged a conference on solar energy in 1996.
- The IEB has organized a national conference on renewable energy for poverty alleviation in 1997. This includes different areas of solar energy, wind energy, wave energy, biogas, and biomass.
- A workshop on solar energy was organized by Local Government Engineering Department in 1997.

Future programmes of renewable energy education

As mentioned earlier, studies on RE, specially solar and wind energies, have been initiated since the mid-1950s in Bangladesh. Since then awareness on these issues is growing among teaching and research institutes here. Now, relevant courses/topics are being offered at all levels of the educational system in Bangladesh. CES of BUET and REW of DU are now planning to soon introduce Masters programmes on RE of one to two years' duration.

Conclusions

The following conclusions can be made:

- BUET, BAU, DU, BIT, and IIT are offering courses on solar energy in both undergraduate and postgraduate levels as selective courses in conventional engineering/applied science curriculum. They also organize seminars/workshops/conferences on RE from time to time.
- Polytechnic institutes offer courses on RE.
- At school and college levels, no formal RE course has been offered but the general science subject includes

topics on the description of solar energy, biogas plants, and windmills.

- BOU offers some non-formal lectures on renewable energy by mass communication (TV) from time to time.
- NAEM, which gives training on educational management to college teachers, also offers a course on RE.
- BUET, BAU, DU, BAEC, and IEB organize workshops/seminars/conferences from on time to time on RE.
- CES of BUET and REW of DU and planning to introduce an independent postgraduate programme on renewable energy of 1 to 2 years duration in the near future.

Malviya Regional
Engineering
College
BH/1, Staff
Colony
Jaipur - 302 017
India

Jyotirmay Mathur*, N K Bansal

Impact-oriented comprehensive approach for energy education

Renewable energy education: current scenario and future projections
pp. 74-79

Abstract

The famous slogan of 'catch them young' should also be applied to energy education. Introducing EE (energy education) at the early stages with increased emphasis on application and research at a higher level is the need of the hour. Rather than teaching only RE (renewable energy), the course structure may be based upon a step-wise approach that can generate sufficient motivation for energy conservation, environmental protection, and use of RE. Starting with basic concepts at the high school level, more involvement in technology can only be afforded at the senior secondary level through projects like making solar water heaters, and photovoltaic energy-driven water pumps. More attention is to be given to the understanding of underlying basic concepts rather than the intricate technical details, which can be taken up at a later stage. Another important part of this mission would be to train teachers for EE. Although, the technology-related details are not proposed to be covered in the curriculum at the school level, still the teachers have to be made technically capable through special training programmes utilizing the expertise of eminent specialists in this field. With this background, the course structure at the postgraduate level may also be altered to suit the requirements of the industry. The efforts being taken at CES (Centre for Energy Studies), Indian Institute of Technology, New Delhi have been mentioned in this paper.

---

*Author for correspondence

Introduction

The current rate of technological advances has brought many changes in the industry as most of these advances have a significant direct influence on productivity, profitability, etc. These advances sometimes play an important role in guiding the direction of education. In contrast, some other advances may not have a direct role but are very important for ensuring a sustainable future. RE is one such field. RETs (renewable energy technologies) are rapidly gaining importance as the energy crisis is growing. Though it has been known for several years that RE has two distinct advantages over non-renewable energy, namely, its practically non-depleting sources and its environment friendliness, RE has started gaining attention only in recent years. RE programmes have got a boost after man has realized the possible impacts of technologies based on non-renewable energy sources, especially fossil fuels. Similar to the way in which society has learnt and started adopting RE, this impact-based learning approach is likely to be most effective in the formal education system as well. This paper proposes a step-by-step approach for EE (energy education) as a whole. It first prepares a background for realizing the importance of RE before it is taught in detail. Following a four-tier approach and based on the mechanism of learning, the following syllabus has been proposed for incorporation in the education system in addition to the existing fifth tier, which is the postgraduate level.

Primary level : Energy in daily life and sources of energy
Secondary level : Impacts of various energy sources
Senior secondary level : Principles of RE
Undergraduate level : Technical aspects of RE

This scheme has two target groups: (1) students who may go for higher studies or research in this field; and (2) students who choose other professions but may be encouraged to use RE systems through proper exposure and orientation. The objectives of addressing these two groups are different. The former aims to prepare students for higher studies by developing a suitable background while the latter is intended to orient them towards energy conservation and encourage them to use RE systems in their daily lives. Ultimately the aim is to bring about awareness of RE in the society and facilitate institutes for higher studies to focus on thorough R&D studies. In some schools and colleges, EE has already been adopted but it needs a systematic induction in the courseware and infrastructure to make it most effective. Modifying the existing courses, offering separate courses, and introducing experiments are some available options.

Creating energy awareness

The success of RE or any other new technology largely depends on its social acceptance. The disadvantages of intermittent supply and low energy density have proven to be hindrances in the growth of RE programmes. Educating the future citizens right from the beginning and guiding them towards realizing the importance of RE may help in this mission, and hence, is the main inspiration for this paper. Instead of directly introducing RE, it is proposed to first introduce students to the need of energy in daily life. RE education can be introduced at the final stage of primary education, almost at the time when a child starts applying his/her own logic to daily events. At this stage, the child must realize that energy is the necessary thread of almost all the activities in the world. Then, the question of 'from where energy comes' arises, where various sources of energy can be explained. The sources can be classified into renewable and non-renewable energy sources. The help of simple 'do-it-yourself' experiments related to daily life examples like lighting a lamp using a PV (photovoltaic) panel is suggested in order to make the children understand the simplicity and practicality of RE and get interested in the subject.

Once they are aware of the various sources of energy, the study can be directed towards the impacts of energy technologies. This may include primarily the environmental impacts along with the depletion of resources caused by each technology. This impact education is to be imparted at the time when the student is mature enough to differentiate between 'good' and 'bad'. Examples can be created for classroom demonstrations or assignment problems to enable better understanding. This extent of EE must be imparted before a student chooses the discipline of his career, be it science, arts, or commerce, i.e. up to the secondary level. This will ensure that any student not opting to study science will also have gained a basic understanding of RE which later on will help building a society having a pre-cultivated interest and inclination towards RE.

Background for higher studies

Higher studies in the field of energy differ from other conventional courses because of their interdisciplinary nature. This essentially demands knowledge of more than one branch of engineering like electrical, mechanical, or chemical engineering. Though the basics of all branches are given at the beginning of the undergraduate level, it has been felt that students going in for a postgraduate degree in the field of energy need be exposed to other disciplines. Moreover, the course duration of four years is insufficient to equip them with the theoretical and practical knowledge of their own branch of study therefore, the basic principles of RE technologies can be explained at the senior secondary level. Providing basic information at the postgraduate level is very often a waste of time for those who have already studied it. To meet this need, some bridge courses can be introduced to help bring all students to a common platform where they will be able to appreciate concepts related to all the fields. This bridge course will allow for free space in the courseware for introduction of more intensive topics related to research. Such an experiment has been proposed in the recently modified course structure of postgraduate programme in the Centre for Energy Studies, Indian Institute of Technology, New Delhi.

The comprehensive approach suggests that basic concepts of RE may be introduced at the senior secondary level. It could begin with the study of the nature of RE sources, principles and potential of RE supported by well-designed experiments and practical work e.g., making a solar cooker. Minor technical details may be left at this stage. Emphasis should be on using these systems and explaining their utility for the society. At this stage, it becomes very important that the teacher is properly trained and motivated to see that the objective is fulfilled. Expertise of eminent specialists in their respective fields can be utilized to train the teachers so that they are in a position to answer the queries and trained enough to propagate the utility of these systems properly.

Energy education at the undergraduate level

Most engineering students in India get employed in the industry, and these technocrats can contribute to energy conservation and use of RE if properly organized. Some subjects being taught do cover a few aspects of energy conservation and RE but the integration of concepts is missing. Application of RE can be identified by various disciplines and may be taken up as projects or seminars towards the final stages. One typical example of such project can be microprocessor-controlled, PV-powered information display systems in which the supply of power to the display panel may be controlled according to illumination level, and surplus power can be stored in an accumulator for use during night. In such a project, though the emphasis may be on the main discipline of the student, this approach will help motivate more students towards this field which has an orientation of integrating RE with hard-core engineering. Students have to be exposed to some detailed concepts related to their branch. Mechanical engineering students can appreciate the thermodynamics of solar water heating systems. For chemical engineers, it could be energy from biomass or alternative fuels. Students of architecture may be taught concepts of passive cooling and heating and so on. As already discussed, a bridge course could cover the deficiencies related to other branches, which means topics like thermodynamics of solar water heating can be taken up by a civil engineer in the bridge course. This approach will avoid the repetition of concepts for some students which was seen as a major problem in running postgraduate courses. With this approach, more time can be devoted to research and technological development.

Effective implementation

When we talk about introducing new topics or courses in the existing system, it becomes essential to discuss the requirement of facilities. For explaining the use of RE and for 'do-it-yourself' projects, laboratories need to be developed in schools where basic facilities like small PV modules, materials, and tools required for making solar collectors or prototypes of windmills are available. Laboratories may even be sponsored by companies producing equipment related to RE. This will also help in marketing RE products. State-of-the-art or technical breakthroughs can be first introduced to the teachers in specially organized seminars or workshops led by specialists in their respective fields. In addition to this, any opportunity to address a large audience e.g., through programmes like 'Students for solar energy' or 'Run for sun', recognizing/awarding contributors in RE, and conducting field visits and invited lectures for students are also suggested.

Proposed changes at the postgraduate level

A feedback was taken from the alumni, present students, industry, and some important agencies. The synthesis of the ideas resulted in the development of a new modular course structure with special focus on the thrust areas. In this scheme, after imparting EE essentials through core courses at the beginning, the course gets divided into modules. These are:

- Industrial Energy and Environmental Management
- Energy Policy and Environmental Management
- Power Management
- Management of Renewable Energy Sources

Each student is supposed to specialize in any one of these fields. The purpose of including environmental studies with energy studies is that energy and environment both need to be looked at together for finding sustainable options for energy in the future. Environmental aspects of various energy systems or their life cycle impacts have already become important with the launch of ISO standards. Therefore their incorporation in the courseware was felt necessary.

Conclusion

The integration of EE into the existing curriculum is important in today's environment. It can only be accomplished by a comprehensive approach at all levels of the education system rather than leaving the task to a few institutes of higher studies. The proposed approach ensures a step-by-step induction of RE into the present education system. In the proposed four-tier system, attempts have been made to match the analytical capability of the student with the type of concepts being provided. The scheme imparts basic RE education to all students and equips science and engineering graduates in suiting the profile ideally demanded by institutes for higher studies in this field of research.

Aerospace
Engineering,
Indian Institute of
Technology
Kanpur - 208 016

Kunal Ghosh

Teaching of wind energy at advanced undergraduate and postgraduate levels

Renewable energy education: current scenario and future projections
pp. 80-87

Abstract

Renewable resources of energy are beneficent to the environment and available in some remote and rural areas. Wind energy is an important renewable resource in the coastal areas and mountain tracts. To harness the wind energy potential, trained manpower at the graduate level is necessary. In the course offered at IIT–K (Indian Institute of Technology, Kanpur), the culture-specific motivational aspects of Indian students are taken care of by a historical study and selected illustrations. India's geographical location has strong influences on the wind resources. The phenomenon of monsoon winds adds to the geostrophic trade winds. Prerequisites of the course, content of the course including aerodynamics, and standalone turbine applications are discussed in this paper. Policy matters that affect teaching, in particular, and engineering educational institutions, in general, are presented.

Introduction

India's energy requirement is expected to keep on growing in the foreseeable future, because of increasing developmental activities. Alongwith fossil fuel power plants, it is necessary to harness all available renewable energy sources. Wind energy is an important resource along our long coastline and numerous mountain tracts. To harness wind energy, trained technical manpower at various levels would be necessary. At the top-most level to fill the role of designers, planners and policy makers, graduate and postgraduate engineers are needed. The course on wind energy offered at IIT–K is aimed at training and educating such personnel.

Motivation

The course content must be culture-specific to some extent in any country and India is no exception. For instance, application of wind energy in ship propulsion using sails and food grain grinding by windmills are part of folk wisdom in Europe. Children there grow up singing nursery rhymes, hearing tales, and looking at pictures of sail-propelled ships and wind-driven mills. But Indian children are not raised on such a diet. In the distant past, Indians were a maritime nation, but in the middle ages crossing the seas came to be forbidden by religious authorities. Although the windmill finds a mention in Chanakya's *Arthashastra*, a famous text in economics, it has not been in vogue for millennia. Hence Indian students would need some specific material for orientation and motivation. To this end, a brief history of wind energy is included in the introductory lectures.

Subsequently, a fairly detailed picture of the brewing global environmental crisis is given. The important role played by GHGs (greenhouse gases) is pointed out. At this stage, a brief history of energy consumption by mankind is narrated. This consumption has grown by leaps and bounds since the Industrial Revolution in the middle of the 19th century and the trend persists. The students have shown much interest in a picture of sailboats (Figure 1) which was lifted from an English classic called *Moby Dick*. Next they are shown a schematic diagram of a modern boat deploying wing sails in cascade formation (Figure 2). When it was pointed out that an enormous amount of fossil fuel is burned every year by ships plying for international trade and about 10%–20% of this fuel can be saved by deploying auxiliary wing sails, students have expressed enthusiasm. When it was pointed out that very little of this sort was being done either by India or the international community, as fossil fuels were cheap, the students have looked baffled and disappointed. At this stage, a discussion is initiated about various international efforts and conventions

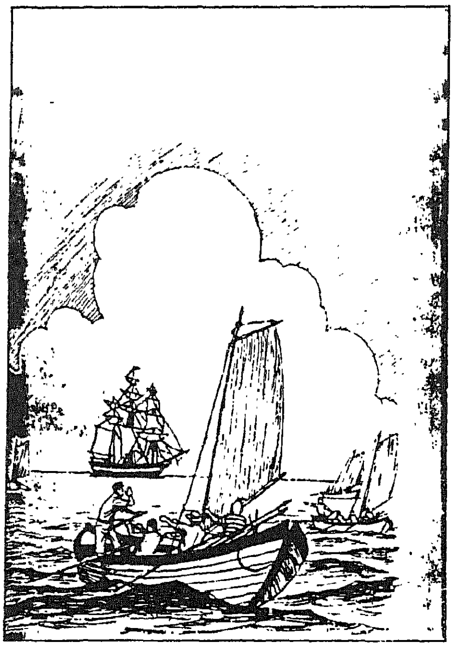


Figure 1 Old-fashioned sailboats

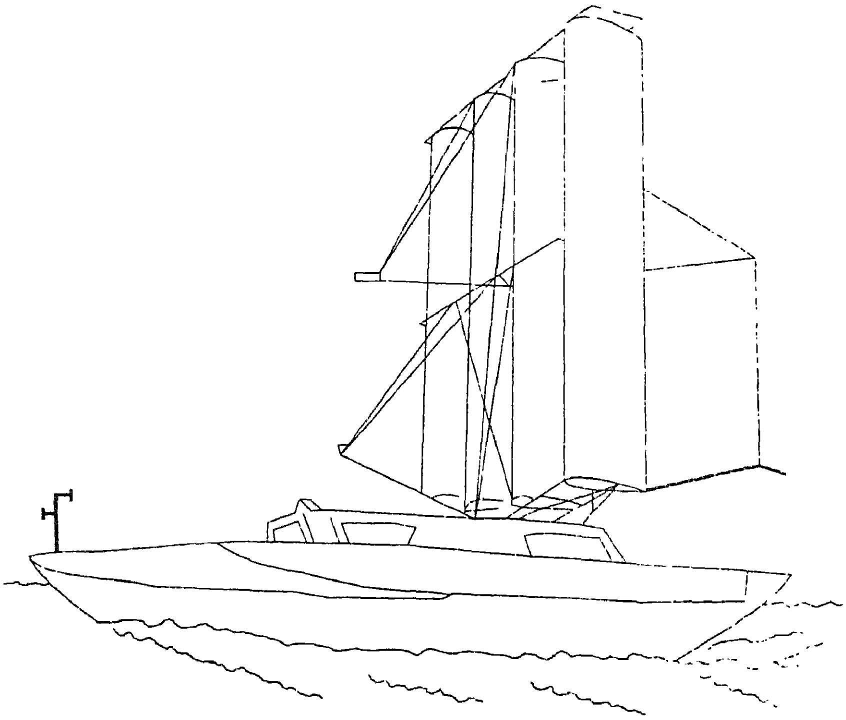


Figure 2 Modern boat with wing sails in cascade formation

Renewable energy education

about cutting down GHG emissions and global environmental protection. Students are encouraged to debate issues and put forth opinions. Some students have suggested that there should be an international convention making modern auxiliary wing sails compulsory for merchant and civil ships.

Again the students have evinced keen interest when the picture of a corn grinding windmill of 16th century Europe is shown by a slide projector. Golding (1976) gives a description of its functions. At this stage, to excite curiosity, a seemingly intractable problem is posed before the students. A sailboat, which has no source of power other than the wind, is required to travel from point P to point Q, while the wind blows in exactly the opposite direction, that is, from point Q towards point P (Figure 3). The solution to this problem is supplied much later, about three-quarters through the lecture course.

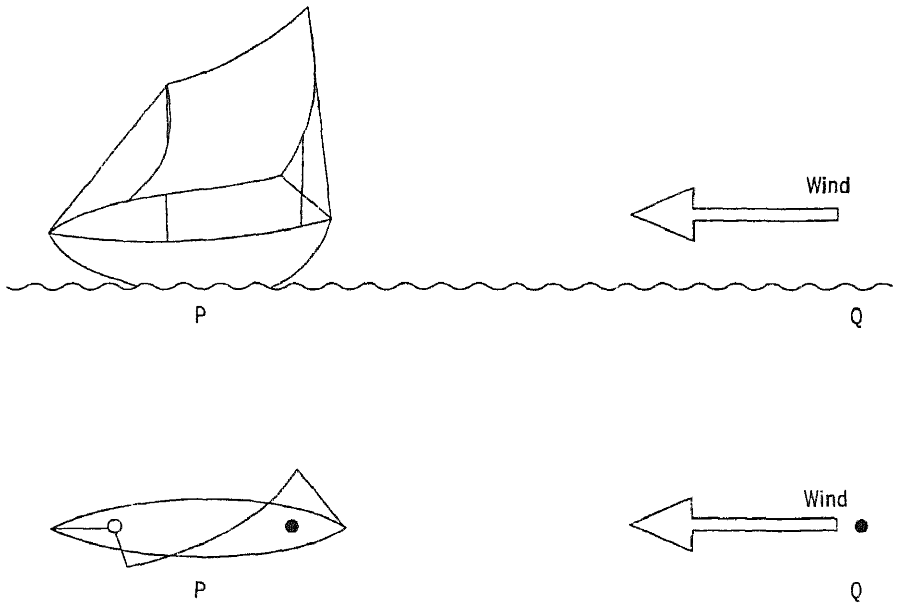


Figure 3 The sailboat problem

Prerequisites

Only those students who have had a prior course in fluid mechanics are allowed into the wind energy course. This background is considered necessary for the grasp of the aerodynamics of wind turbine design and control. The last topic involves interaction between the prime mover and generator, and interaction between a wind farm and utility grid. This course is offered as an elective open to students majoring in aerospace, mechanical, and electrical engineering.

India's wind resources

India's wind resources are to be looked at in the context of global wind systems. Hence the general pattern of global geostrophic winds is discussed. Different atmospheric wind cells such as Hadley cell, and Polar cell are presented (World Meteorological Organization 1981). Coriolis acceleration and its effect on winds are explained. Measuring instruments (anemometers) and organization of wind data are discussed. Standards techniques for organization of data using Weibull distribution are covered from Twidell and Weir (1986).

India straddles two global wind zones. The extreme North (Kashmir and Ladakh) is in the zone of mid-latitude westerlies. The rest is in the north-east trade wind zone. The two zones are separated by the band of sub-tropical high where the wind speeds are very low. This lies over the North Indian Gangetic plain.

Summer and monsoon winds

The summer and monsoon winds are a local subcontinental phenomena. They are very important for India because for about five to six months (April to September), considerable intensification of the wind resource takes place. In the extreme South, there is also the reverse winter monsoon (from November to February). That is why peninsular India is so rich in wind resources.

Aerodynamics of wind turbines

Airfoils

Airfoil geometry and nomenclature, such as National Advisory Committee for Aeronautics and National Aerospace Administration four, five, or six digit series are covered. The airfoil theory is presented in brief. Much greater emphasis is placed on discussing airfoil properties, such as roughness tolerance, gradual or sudden stall, and lift–drag radio. How a wind turbine designer makes a very careful choice of an airfoil or a combination of airfoils is discussed in detail.

Airscrew theory

Aircraft propellers, helicopter rotors, and wind turbine rotors belong to the same category of airscrews for their essential similarity of operation. Glauert's Airscrew Theory (Durand 1983) and his concept of ideal and turbine are presented.

Rural and remote area usage

Rural areas are often far away from any utility grid. Here standalone turbines are of great advantage. Ghosh (1991, 1992) has worked on the design of the rotor of FC 4000 wind turbine. Students are taken through the stages of its development by means of colour sides. FC 4000 is a multi-purpose turbine, which can be harnessed for battery charging, heating and cooking, and water pumping (Figure 4). Water pumping is another important application of a standalone machine. Le Gourieres (1982) gives a treatment of this subject, which proves very popular with the students.

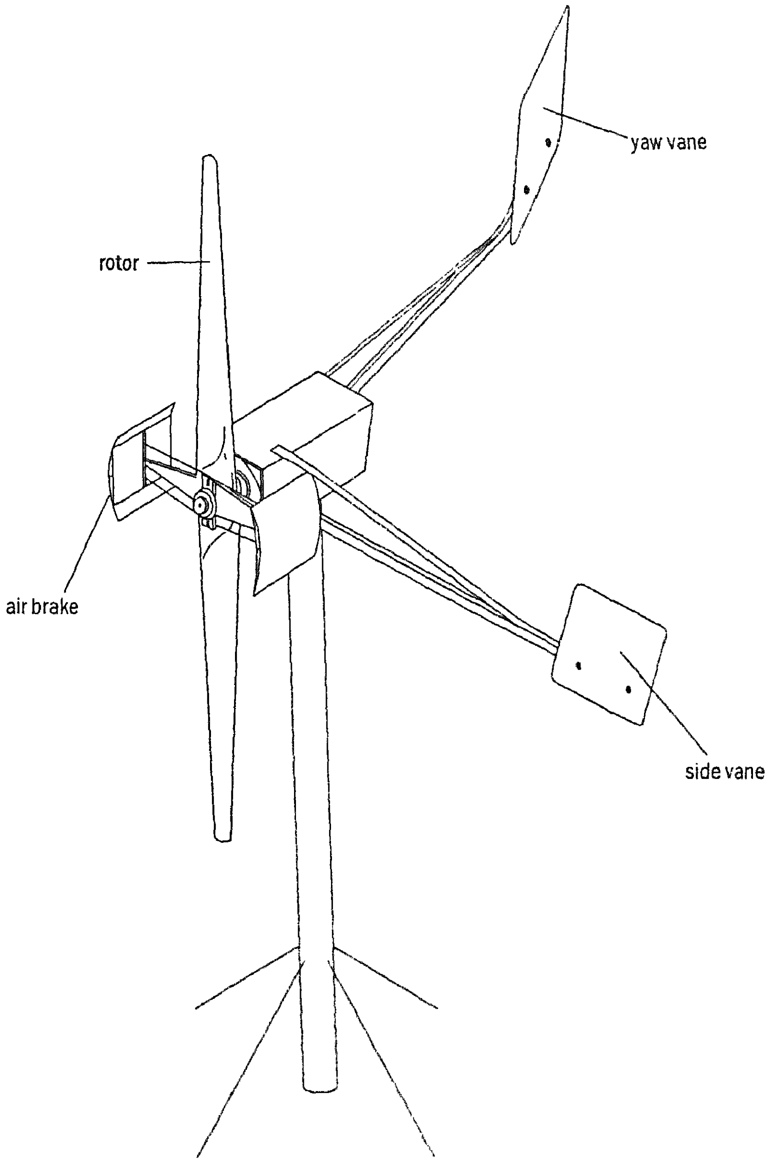


Figure 4 FC 4000 - a multi-purpose wind turbine

Policy issues related to teaching

Indian engineering colleges tend to put greater emphasis on learning theory and software whereas practical aspects, hands-on experience, and hardware development do not receive the attention they deserve. One way to correct this imbalance is to offer the opportunity to the teaching faculty of doing Research and Development with wind turbine hardware and product development. This requires close collaboration between the wind turbine industry and teaching institutions.

There was a panel discussion on the penultimate day of the all-India workshop-cum-seminar on wind energy (18–19 September 1993) in Chandigarh. The author, who was on the panel, recalls that there was a divergence of opinion on the question of R&D in India and teaching institutions in particular. It is necessary to resolve such issues and put in concerted efforts in teaching wind energy in our educational institutions. To expose students to the practical aspect, visits to wind turbine sites should be organized. This again calls for close cooperation between industry and academia.

The author tries to supplement classroom training by laboratory activities and field visits. Lectures are often complemented with posters of wind turbines showing fair amount of details. A video cassette and a 16-mm film on wind energy are shown to the students followed by a question–answer session.

Wind energy is a subject which is interdisciplinary in nature involving aerodynamics, structure, and power train design, which draw upon aerospace and mechanical engineering. Electrical power generation and controls are essential components of wind energy and these are drawn from the discipline of electrical engineering. It is desirable that a course on wind energy should attract students from all three major engineering disciplines mentioned above. However in IIT-K, the students of electrical engineering seem to stay away from this course so far.

Students at IIT-K usually get good employment openings soon after graduation or postgraduation. However, their obtaining training in the area of wind energy seems to make little difference. As a result, student interest has declined of late. This again points to necessary change in policy of the Indian wind turbine industry.

References

Durand W F. 1983
Aerodynamic Theory Volume 4
New York: Dover Publications.

Ghosh K. 1991
Design and Construction of a Rotor for FC 4000 Wind Turbine
Report of Folkecenter for Vedvarende Energi of Denmark, July 1991
Also appeared as Selected Article in *ASSET*, 14(2), 1992, published by United Nations University and Tata Energy Research Institute.

Ghosh K. 1992
Use of NASA LS(1) General aviation airfoil for a small wind turbine: an experience in Denmark
In *Proceedings of the Technical Session of the 43rd Annual General Meeting of Aeronautical Society of India, Hyderabad, 7–8 February 1992*
Also published in *Journal of Aeronautical Society of India* 44(2), May 1992, pp.105–109.

Golding E W. 1976
The Generation of Electricity by Wind Power
London: E. & F N Spon Ltd.

Le Gourieres D. 1982
Wind Power Plants, Theory and Design
France: Pergamon Press.

Twidell J, Weir T. 1986
Renewable Energy Resources
London: E & F N Spon Ltd.

World Meteorological Organization. 1981
Meteorological Aspects of Utilization of Wind as an Energy Source
Geneva: World Meteorological Organization.

Science
Department,
The American
University in Cairo,
Cairo
Egypt

Salah Arafa

Renewable energy training for desert development

Renewable energy education: current scenario and future projections
pp. 88-101

Abstract

Egypt is embarking on large national projects aimed at moving about 20 million people – mostly young, unemployed graduates – out of the Nile valley and delta to the desert areas of Egypt. There is a need to prepare the public and the university graduates for such a drastic change.

A renewable energy training programme has been designed for the task of desert community development. The programme is sponsored by a number of Egyptian NGOs (non-governmental organizations) and partially supported by small grants from the UNDP/GEF (United Nations Development Programme/Global Environment Facility). It is tailored to the needs of the target group and has four main components:

1. Public awareness (one-day activity)
2. Introduction to RETs (renewable energy technologies) (one-day activity)
3. Systems (each sub-component is a one-week activity)
    a) for houses
    b) for farms, small projects, and small industries
    c) for communal systems
4. Installation and maintenance (two-week activity)

This paper presents the components of the programme and their impacts on community development. The programme was tested for the idea of developing a new solar energy desert community called New Basaisa in Sinai. It is planned to implement the programme in a large number of communities which act as an open air laboratories and classes for the programme. The programme should be initiated by the summer of 2000.

Education and training in renewable energy

Education in RE (renewable energy) has many aspects. Usually, the attention goes towards its science and engineering aspects. Other dedicated educational activities address, for instance, health, safety, environmental or macroeconomic aspects. In the present paper, the focus is on social and microeconomic aspects of RE. It is argued that RE plays a crucial role in the potential for further dissemination and diffusion on today's main markets for renewables. It is obvious that RE is a truly multidisciplinary subject that needs contributions from a variety of educational disciplines. A broad distinction should be made between degree programmes, postgraduate courses, and public courses. Strictly, the first two should be referred to as education, and the last one as training.

Postgraduate courses in RE are more flexible and allow the option of a multi- or even interdisciplinary approach. Examples abound of many training courses that take participants from various backgrounds. A precondition for an effective course is to have dedicated and experienced teaching staff, from a range of disciplines, working together in curriculum development and teaching. The curriculum incorporates a balanced mix of science and engineering principles and concepts, technology assessment, economic analyses, social science issues, planning and management, policy discussions, and preferably a lot of case studies that bring many disciplines together in problem analysis. The general approach of the training should be demand-oriented, i.e. how to find solutions for needs, rather than how to find problems that match a technical solution.

In rural regions, it makes sense to think in terms of energy technology systems. Field experiences teach us that just parachuting an energy supply technology into a rural community has little effect, if any. In order to function, an energy technology needs regular inputs, auxiliary equipment, appliances, maintenance and operation skills, an infrastructure wherein the products and by-products can be utilized, management and support structures, preferably a technological infrastructure capable for local manufacture of the equipment, and often a system for credit or subsidy. All these together constitute an energy technology system.

We cannot take it for granted that in rural or desert areas all the elements of an energy technology system are available. Obviously, the costs of an RET (renewable energy technology) include many more components than just the cost of acquisition of the equipment. The environment's social and economic benefits may be appreciated by the government, but they are often hard to quantify in terms of money. What are actually identified and included as components of economic costs and benefits of small-scale energy technologies should result from site-specific technology assessment and socio-economic evaluations. Both cost elements are site-specific, particularly in rural areas. This means that the costs depend very much on local conditions, as is common knowledge for hydropower units.

We should differentiate between dissemination and diffusion of a new technology. Dissemination refers to spreading in some guided way, whereas diffusion refers to a mechanism with no apparent outside intervention. The important question then is why are RETs not easily disseminated or diffused? Lack of awareness is certainly not always the bottleneck in the dissemination of a technology amongst potential users. We should not just assume that envisaged users have an in-built resistance to change. People living in certain communities know their own priorities better than a promoter of a technology can ever do. Take an example from the promotions of biogas. In a certain country, on an average, two family-sized digesters are already present in every village. Still, the government continues to put in substantial efforts and money for creating 'awareness' on biogas amongst villagers.

Very little attention has been given to the lack of supporting infrastructure, local markets, and users' requirements. It seems that the key to diffusion of RETs as with consumer goods, lies in the existence of technical cadre and local manufacturing. However the infrastructure required for the application of energy technologies is more diverse and more complex than for most consumer goods. In such programmes, it has been observed that very few people are willing or can afford to adopt a technology which costs them money in lieu of time saved (e.g., time for free gathering of fuelwood). However, as soon as tree planting is directed to the generation of cash (for instance with fruit trees), the position changes. Biogas, by contrast, is experiencing more difficulties in the same country, as it mainly serves to improve the quality of life. It is quite possible that income-generating energy technologies can spread through diffusion, provided the supporting infrastructure is present or is being built up.

Technologies that do not generate income are to be spread mainly by dissemination, particularly to weaker groups of society, which require interventions and support. Specific to these technologies is the fact that they are too small to be of interest to utility firms, and too big for many private parties. These systems must be organized or combined in order to be financially and organizationally feasible. The first strategic choice is between diffusion and dissemination. The choice may not be free as it depends on the merits of the technology and the facilities available to the manufacturer or distributor.

The key question is how the envisaged user could, if at all, acquire the technology for an attractive price in his neighborhood. It means that the issues of inputs, spare parts, local servicing, and credits must be considered and solved. It may be justified to subsidize the technology in the initial phase of its introduction, so as to familiarize the public with the favoured product and to establish a minimum economy of scale for local production and servicing.

In the long run, it may be more effective to direct the money to measures which aim to improve the general income of the group concerned. Subsidy on a small-scale energy technology can be justified for environmental reasons, for instance, to promote clean RE. Here environmental costs are not yet included in the financial cost of alternatives which harm the environment. The easy channel for this subsidy would, again, be via producers or dealers. Guided dissemination of small-scale RETs is sometimes taken up in development projects and programmes of a wide scope. Here, the technology is very much a tool to serve the purpose providing for training and setting up maintenance for dissemination. It is too often assumed that it would be sufficient to direct dissemination activities to awareness creation alone. The existing organizations should be agents of change and act as intermediaries for the (new) energy technology. Examples are agricultural extension services, irrigation schemes, NGOs (non-governmental organizations), some religious organizations, schools, market places, etc.

Projects for dissemination of small-scale energy technologies usually aim at development. As with other development projects, user participation, proper monitoring and control, and communication of the results of project evaluation should be given proper attention. There should be a lot of case studies which bring many disciplines together in problem analysis. Weakness in policy concepts will leave the trainee with techniques that cannot be applied for a sensible goal. On the other hand, negligence of methods or techniques will result in lack of operational effectiveness. It is better to enable the trainees to serve in professions related to the applications of renewable energies. Via the market mechanisms as indicated above, professional competence will lead to enhanced applications and use of REs.

The American University in Cairo and Basaisa-IRTECTAP

The AUC (American University in Cairo) began its educational activities beyond traditional academic work in 1924 with the establishment of the Division of Extension. Later renamed the DPS (Division of Public Service), it now operates as the CACE (Centre for Adult and Continuing Education). All its programmes and activities have a respected place in Egypt and other countries in the Middle East and Africa. They were a source of inspiration and served as models for similar activities initiated during the 1980s in Egyptian national universities. A long-standing commitment of the AUC to rural community development is exemplified in the Basaisa village integrated field project in the Nile Delta Governorate of Al-Sharqiya. Since 1974, the AUC faculty, students, and staff have been actively involved in that project for awareness, education, and training programmes on site in the village. In 1985, AUC in cooperation with the ADF (African Development Foundation) supported the Basaisa–CDA (Basaisa Community Development Association), a grassroots NGO in Al-Sharqiya Governorate, to construct a technical centre at the site of the named village, called the Basaisa–IRTECTAP (Basaisa Integrated Rural Technology Centre for Training and Production).

The Centre's mission is to provide opportunities for the inhabitants of rural communities in the Basaisa village region (especially youth, women, and children) to advance socially, economically, and technically as individuals and as groups to actively participate in the development of their communities. The centre carries different programmes in the fields of public- and community-based activities. These activities can be classified into five categories:

1. Public awareness and education
2. Training
3. Services
4. Production
5. Research and development

These activities are aimed at increasing labour and land productivity and providing trainees with skills to compete in the work market and to actively participate in the development activities. The centre has been able to train a large number of youth graduates in the above stated areas.

Training for desert development

There is an acute population distribution problem facing Egypt today and will perhaps worry future generations as well. According to most conservative estimates, the population in Egypt is expected to increase by around 20 million persons over the coming 20 years, despite sustainable family planning efforts to achieve gradual reduction in the population growth rate. This increase will take Egypt's population in 2017 to over 80 million. This makes it inevitable to plan and regulate the spread of population over all the parts of the country and necessitates a move out of the Nile delta and valley towards the desert. Also, about half of the present Egyptian population is aged under 20 years. This large group represents the future of Egypt and it should be the focus of major development investments. Social institutions, cultural, educational, and scientific organizations, and religious and political institutions, should coordinate activities to provide an integrated development programme tailored to the needs of the Egyptian youth. Through an analysis of the demographic information on population distribution, it is possible to divide the country into three categories.

- Heavily-populated urban areas where PD (population density) = 1200–32 000 persons/sq. km
- Areas of intermediate density like medium cities and small towns where PD=22 persons/sq. km.
- Low density zones where PD=below one person/sq. km

The discrepancy is a result of the greater concentration of socio-economic activities and the wider availability of services in large cities, which increase their attractiveness.

Currently, there is no three-pronged effort, as described below, to reach the goal of equitable distribution of population.

1. Reduction of the natural population growth rate, especially in large cities, through efficient family planning programmes
2. Strengthening of the socio-economic development in rural areas to stem the flow of internal migration to large cities
3. Establishment of new desert settlements and satellite cities to absorb the growing population

Egypt is losing valuable agricultural land to expansion of housing and it is necessary to get people to settle on non-agricultural land. The 20 new cities constructed to date in Egypt have a problem of low rate of absorption (only 7% of the target rate). What are the constraints? And how does one solve the problems of new settlements? What is the role of NGOs?

In 1991, Basaisa–IRTECTAP, in response to the problem of unemployed university and high-school graduates – a national problem felt severely in rural areas – initiated a programme for training youth for employment. The idea was to complement whatever the graduates had learned by a number of needed and necessary skills which would add quality to their education and personalities and enable them to compete in the open work market. During one of the community's open discussions, a group of three or four young graduates indicated an interest to move out of their crowded villages and seemingly hopeless working situations and migrate to a desert area of Egypt to work together to form a small community based on cultivation. Their main question was whether the Society (Basaisa–CDA) was willing to support such a project and secure a collective loan for their start. The idea was extremely interesting and appealed to many. The subsequent meeting of the Basaisa–CDA board had the issue on its agenda. The board approved the principle of supporting this initiative and the idea of a New Basaisa Community was born. The Basaisa-IRTECTAP was asked to design an integrated training programme for desert development.

The overall aims drawn up for the training programme reflect the following considerations:

- to provide an adequate level of awareness, education, and training in technologically and economically viable technologies for desert communities with special reference to renewable energies and irrigation techniques as well as habitats and environmental protection technologies;
- to provide this education and training through acknowledged experts, recognized field practitioners, and NGO leaders; and
- to structure the programme in modules.

This will ensure that participants will first get basic knowledge and information in the different fields of interest to desert community development in Module A. In Module B, they will be exposed to a specific technology for further in-depth treatment. Module C is more technical and oriented to practical hands-on workshops to train local cadre interested in using their knowledge and training for paid work within the region of their communities. Also an integrated programme (modules A+B+C) could be structured for intensive training courses.

The above aims have been translated into specific learning and vocational objectives:

- understanding of the limitations, efficiency, costs, environmental impacts, and conversion technology of non-renewable energy sources;

- assessment of the needs of desert communities in terms of cultivation, energy, environment, and sustainable development;
- basic knowledge of power sourced from solar, wind, and biomass/waste;
- in-depth knowledge of at least one of the above renewables and at least one of the appropriate technologies proposed;
- experimental skills in instrumentation, data collection and data processing, installation, and operation and maintenance of at least one of the proposed (and available) technologies;
- practical involvement through a field project;
- data to make the right choice, and ample comparison to make the right selection; and
- ability to integrate the subjects within a framework related to the main problem of energy, environment, and community development.

Elements of the lectures, seminars, and discussion workshops

- Basic principles of energy and work
- Forms of energy
- Sources of energy
- Energy conservation
- Why renewable energies - solar?
- Spectrum of sunrays
- Uses of the different regions of the spectrum
- Solar energy systems
- Photovoltaic and applications
- Solar water heaters
- Solar dryers
- Solar cookers
- Solar distillers
- Biogas technology
- Energy and development
- Energy and environment
- Assessment of community needs
- Moving out of the Nile valley
- Maintenance and repair issues
- Guarantees for technical systems
- Financing
- Sustainable community development

Elements of the practical workshop

- Solar heating and applications
- Composing
- Installation of photovoltaic systems
- Energy conversions–concentrators

Table 1 General timetable for the integrated course (hrs)

Day/Time	7	8–12	13	14–17	17	18–21	21	22–24
Day 1 Thursday		Arrivals		Arrivals		Accommodation orientation		
Day 2 Friday	B	Opening introduction		Activities, workshop		Lectures, seminars		
Day 3 Saturday	R	Lectures, seminars	L	Activities, workshop	D	Lectures seminars	D	
Day 4 Sunday	E	Lectures, seminars	U	Activities, sports	R	Seminars, computer	I	F
Day 5 Monday	A	Lectures, seminars	N	Activities, field visits	I	Seminars, computer	N	R
Day 6 Tuesday	K	Lectures, seminars	C	Activities, workshop	N	Seminar, computer	N	E
Day 7 Wednesday	F	Lectures, seminars	H	Activities, workshop	K	Lectures, seminars	E	E
Day 8 Thursday	A	Lectures, seminars		Activities, workshop	S	Lectures, seminars	R	
Day 9 Friday	S	Lectures, seminars		Activities, field visits		Seminars		
Day 10 Saturday	T	Evaluation		Graduation reception		Departures		

- Tree planting
- Construction of biogas plants
- Solid waste treatment

Elements of the field visits

- Waste treatment sites
- Solar powered houses
- Biogas plants
- Model desert farm
- Desert architecture – Hassan Fathi model
- Desert development research centres

The major themes

Solar

1. Conversion of solar energy into heat (solar thermal),
2. Conversion of solar energy directly to electricity (solar photovoltaic),
3. Conversion of solar energy to plant, vegetables, or other biological forms and application of solar energy to convert these into usable forms of fuel (bio energy), and
4. Indirect application such as harnessing of winds, waves, temperature gradients from ocean etc.

Solar thermal These systems are broadly categorized as:

1. Low temperature range – solar water heaters, solar air heaters, solar dryers, solar passive buildings etc. having a maximum operating system upto 100°C.
2. Medium temperature range – solar cookers, solar refrigeration and air conditioning, solar pumping, industrial process heating, etc. having temperature between 100°C to 250 °C.
3. High temperature range – suitable for solar thermal power generation where operating temperatures are above 250°C.

Solar photovoltaic Solar cells for direct generation of electricity from sunlight are suitable due to ease of installation and low maintenance for low power application in remote places. Besides the power cells, storage in battery form is to be arranged for application at night.

Biomass There are several methods for the transformation of biomass into usable energy. The simple one is direct burning of solid wood or other plants. The second is the conversion of biomass into liquid. A third method is the biological process in which bacteria break down organic waste into methane gas. Bioenergy can meet the energy requirements of rural households to a large extent.

Biogas The gas generated by anaerobic fermentation of animal and human wastes may not be a high calorific fuel like petroleum gas, but can serve all the domestic requirements of heating and lighting. However, biogas plants in rural areas may pose a problem by depriving the poor of the animal wastes generally collected free of cost. Plant residue is alleged to increase the insect population. Biogas digesters using all types of organic wastes have very high potential both in small- and large-scale applications.

Wind Wind energy may have the advantage of availability during day and night but that is restricted to windy places, which are not so common in this country unlike places receiving direct solar energy. Once again, at places of high wind, energy density may be as high as 15 500 W/m^2 and the conversion efficiency of advanced turbines is about 30%. Generation of electricity from wind requires further conversion with the help of electric generators. The cost, at least in Egypt, is comparable to solar photovoltaics but indigenous manufacture can substantially reduce the cost of wind generators and locally-manufactured wind pumps for water lifting and pumping can overcome the cost barriers. The windmills can be both large and small but the optimum size, even for large-scale electricity generation, is not above 300 kW for rural applications. Small generators of 5–10 kW capacities are considered better in view of maintenance. Undoubtedly, the potential of wind energy is enormous. Even today there are about 0.2 million villages in our country without electricity. Out of these, about half are remote places. In such places, wind generators will be economically viable. Besides, a large amount of diesel is spent every year in pumping water for irrigation. We should be able to save considerable amount of diesel oil by using windmills.

Other sources and other topics

Other energy sources like micro/mini hydro, geothermal, etc. have been defined and briefly discussed. Emphasis is also placed on enhancing knowledge and awareness among the trainees about the relationship between population, energy, environment, and sustainability in community development. The programme includes lectures and seminars on the following additional topics:

- population and environment,
- climate change,
- human development,
- sales and marketing of renewables,
- development communication and promotions,
- accounting and feasibility studies,
- role of NGOs,
- partnership with other sectors,
- policy and decision makers, and the private sector,
- irrigation techniques for desert land,
- recycling of water and wastes,
- buildings for desert areas, and
- community planning and management.

Video clippings were also used in training, showing other field experiments and experiences as well as technical presentations that are difficult to perform during the allocated time.

The New Basaisa: an eco-desert community in Sinai

In 1991, the newly-established Basaisa-IRTECTAP started the implementation of a unique indigenous programme of training youth graduates for employment. This was a response to the problem of youth unemployment in the area and aimed to help them find job opportunities on site.

In 1992, a group of young university graduates from Basaisa and its neighbouring communities asked for

Basaisa–CDA support to study the feasibility of constructing a small community in the Egyptian desert. None of these young graduates alone could afford it or take the risk, but a group working together might be able to do it successfully, if supported morally, technologically, and financially. The group expanded in membership as they got together nearly every week over a period of eight months to study the project and document the agreed general rules for participation, the objectives, and the realistic plans for implementation.

In December 1992, the dream started to become a reality. The new community is based on the idea of cooperative and communal production, services, and marketing. Whenever possible, the community uses appropriate new RETs with overall protection policies of culture and environment.

Location

The New Basaisa community lies 10 km from the town of Ras-Sudr and 10 km from the Ahmed Hamid's tunnel. It covers a total area of 700 feddans by the Gulf of Suez. It is at a distance of 180 km from the centre of Cairo and 200 km from the centre of Zagazig, the capital of Al-Sharqiya Governorate.

Planning and governance

This new community in the desert of Sinai was planned to be a small eco-community – agriculture-based, productive, and protector of the culture and environment. The car roads in the community are well-separated from those for pedestrians for individual security. Car parks are available for every member of the community. There is a special style for the housing, the streets, and the exteriors guaranteeing shades, beauty, culture, and comfortable living in the desert weather. Each member of the new Basaisa community has 400 m^2 for housing. Buildings should constitute not more than 50% of the area and the remaining is used for gardens and green spaces. The houses are in two collective sites, guaranteeing privacy, public beauty, convenience, quietness, reliable natural air conditioning, and cleanliness. Domes are used with natural materials and orientations to get maximum air-conditioning inside and outside the buildings. The service site consists of a collective house for labourers, a visitors'/training house, a number of collective workshops, and a building for the local NGOs.

The two NGOs on site are:

1. Wadi-Sudr Agriculture Cooperative: a multi-purpose agriculture cooperative for agriculture development, and
2. Kenouz Sinai: a community development association for social and economic development.

All buildings are lit with solar energy from photovoltaics and served by biogas plants. There are also a number of solar cookers and distillers.

The two resident sites have a total of 100 lots for houses. Each site will have a common centre which will contain a common room, a library, a video room, a music centre, washing machines, a drier unit, a supermarket, and space for some indoor sports activities. Spaces for outdoor sports activities like soccer, volleyball, and basketball as well as a racetrack are also planned.

The general assembly and a board of responsible people headed by an elected general supervisor govern the new community. The board meets monthly; usually on the third Friday of each month. The meeting is conducted on site and often extends to the next day.

Development

The planning and implementation work started in November 1992, and the practical work on site on 1 January 1993. The pioneers were the first group of young graduates from the Basaisa region, Al-Sharqiya Governorate. In the first phase of the project, a communal house was built and lit by solar photovoltaics and a few water wells were dug. The analysis of the pumped water and soil gave very promising results. Windbreaks were planted and few feddans cultivated for wheat and olives.

At the beginning of the second phase in April 1994, many professionals, intellectuals, private investors, and university professors, who were convinced that the idea was a modest way to contribute to solving some of the country problems, asked to join the new Basaisa group and participate in the development of the community. The two NGOs were officially operating and a new building was constructed to house these organizations and start serving the Wadi-Sudr population. This has strengthened the relations between the Bedouins and the Basaisa group and increased the inhabitants' participation. Almost 20% of the total land area has been reclaimed and cultivated. Also four individual houses for the members have been built. Community administration has been restructured and group meetings have been scheduled.

The third phase started in April 1997 and till today almost 85% of the land has been cultivated and six houses solar powered by photovoltaics and served by biogas plants. A small group of contractors has been formed and activities generating small incomes have started.

On 22 October 1998, the training course was held for the third time in New Basaisa to enable a local cadre of young people in promoting and aiding in the settlement process of RETs for desert community development.

Conclusions

A training programme has been designed for local cadre of technical staff, promoters, and end users. It consists of theoretical and practical work sessions, including:

- basic concepts of RE sources, technologies, and applications;
- basic education about population, environment, and sustainable development;
- basic principles for eco-desert communities; and
- hands-on experience in construction, installation, and maintenance of systems.

This training programme has helped the pioneering group to create and construct a new eco-desert community based on the use of RETs and cooperative production, marketing, and services. The aim is to finish the fourth phase before the end of this century and use the site of New Basaisa, with the help of Kenouz Sinai Association, to offer regular winter and summer schools based on the present training programme. The schools will be open for participants from different areas of the world. They should have interest in RE and other appropriate technologies for desert eco-community development.

Acknowledgements
I want to express my gratitude to the Basaisa–CDA and Basaisa–IRTECTAP members for their many important discussions and contributions. I also want to thank the AUC for the support and encouragement given to me. The technical help provided by ASET and by Misr-America Companies is also very much appreciated.

Session II

Vocationalization of renewable energy education/Training and awareness programmes

■

Training programme on solar energy utilization
R Saravanan

■

Syllabus design of rural technology course for technician diploma in mechanical engineering in Nepal
Riddhi Ratna Sthapit

■

Energy education and capacity building of NGOs: TERI's experience
Shirish Sinha

■

Teaching and training communities of Kathmandu Valley in the use of solar parabolic cookers
Sama Shrestha

■

Renewable energy education and training for integrated rural development
Subodh Kumar

■

Teaching peasants how to build more energy-efficient houses
Jorge Mitchell

Vocationalization of renewable energy education/Training and awareness programmes: summary

Renewable energy education: current scenario and future projections
pp. 105-107

Chairpersons

- Dr Shyamala Abeyratne
  Country Director, Winrock International-India
  New Delhi, India
- Dr VVN Kishore
  TERI, New Delhi, India

Rapporteur

- Ms Pamposh Bhat
  Programme Coordinator, Asian and Pacific Centre for Transfer of Technology, New Delhi, India

The first speaker, Dr A N Rao from the Centre for New and Renewable Sources of Energy, briefed the delegates about the training programme on solar energy utilization sponsored at Anna University, Chennai by the Department of Science and Technology, Government of India and the UNU (United Nations University) in Tokyo, Japan. The programme develops human resources for the RE (renewable energy) industry in the Asia-Pacific region. Students shortlisted by the UNU are offered graduate courses. Many trained personnel have taken up R&D activities, while a few have opted for manufacturing. Dr Rao stressed the need for strong follow-up to popularize REE (renewable energy education) among students of the Asia-Pacific region.

The second presentation was made by Dr Shyamala Abeyratne, Country Director, Winrock International-India. She spoke about activity of the REPSO-India (Renewable Energy Project Support Offices in India) activity vis-à-vis capacity building for RE development. Winrock International-India is an NGO with REPSO offices in India, Indonesia, Philippines, Brazil, and Guatemala. Offices will soon come up in China and Nepal as well. The proposed activity of REPSO in India is capacity building but barriers like lack of awareness need to be overcome. New projects of commercialization of renewables, photovoltaics, cogeneration, small hydro, and wind will be taken up shortly. Training needs in RE systems have to be addressed first. As regards solar energy, REPSO supports local cooperatives and NGOs like SELCO (Solar Electric Lighting Company) to reach the poorest of poor in far-flung areas of India. Recently, REPSO launched its web site <http.renewindia.org> with special features like mailing lists and a discussion group. REPSO's future actions will focus on involving the private sector in RE and its awareness through education.

Mr Riddhi Ratna Sthapit of the Mechanical Engineering Department, Thapathali Campus, Kathmandu in Nepal made the third presentation. Mr Sthapit informed the delegates of curriculum development incorporating REE, for instance diploma-level courses to train technicians. This is done essentially to make up for the lack of trained middle-level managers to work in the rural areas. The Thapathali campus stresses on rural sociology and psychology and entrepreneurship, and helps successful students in placement and training.

Mr Shirish Sinha made his presentation on *Energy education and capacity building of NGOs: TERI's experience.* He spoke at length on the programme's objectives, barriers, and lessons. The objective is to sensitize NGOs to rural energy issues, provide them with technical training, and help in the integration of a rural energy plan over all developmental processes, the barriers being low awareness, lack of information sharing, and limited technology information. The lessons learnt from the programme include the fact that NGOs are aware of energy issues but do not have the proper prospective to deal with the issues. Also, focused training programmes and hands-on training are essential for successful implementation of renewable energy technologies.

Next, Ms Sama Shrestha from the Centre for Rural Technology, Nepal spoke about teaching and training the communities of Kathmandu valley in the use of solar parabolic cookers. She also presented the Centre's activities, including demonstrations through educational institutes as promoters, involvement of health institutions to reduce water-borne diseases, and creation of a clean environment. Ms Shrestha spoke about the Nepal government's initiative to give 50 per cent subsidy on solar cookers. She praised the role of educational institutes and the media in popularizing parabolic cookers in the Nepalese communities.

The last speaker was Dr Subodh Kumar from the Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development, a joint venture of the Ministry of Non-conventional Energy Sources and the Government of National Capital Territory, Delhi, set up in 1992 to promote the integrated approach to sustainable energy planning and rural development, and to impart training. He gave a brief of the institutional activities, which include training programmes for IREP (integrated rural energy planning programme) personnel sponsored by government and private organizations, and education of unemployed youth to enable them to take up employment.

Dr Abeyratne thanked the delegates for their participation and the speakers for their presentations and concluded the session.

Centre for New
and Renewable
Sources of Energy
Anna University
Chennai - 600 025
India

R Saravanan*, G Karthikeyan, R Sethumadhavan, S Renganarayanan, A N Rao

Training programme on solar energy utilization

Renewable energy education: current scenario and future projections
pp. 108-112

Abstract

Sustainable outcomes from remote rural electrification projects are inextricably linked to customized education and training. Such programmes are critical to technology uptake strategies and fundamental to an appropriate technology formula where the benefits flowing from rural electrification occur to communities at the centre of development efforts. In the process, appropriate education and training help to reduce project costs, contribute to the pool of knowledge which is critical for successful project replicability, and importantly add value to the human capital of a given community. From these perspectives, this paper outlines the needs for education and training in RETs (renewable energy technologies) for sustainable projects and presents the training programme on solar energy utilization for the participants from developing countries sponsored by the Department of Science and Technology, Government of India, and the United Nations University, Japan, and organized by the Centre for New and Renewable Sources of Energy, Anna University.

---

*Author for correspondence

Introduction

The late 1980s and early 1990s saw the emergence of world-wide concern regarding the environmental consequences of heavy dependence on fossil fuels, particularly global warming, urban air pollution, acid rain, etc. Currently, a near consensus appears to exist that RE (renewable energy) would need to be promoted if global energy supplies are to be placed on an environmentally sustainable path.

There is little doubt that the global energy demand will continue to grow mainly due to industrialization of the developing countries. RE will play an increasingly important role in meeting the rising energy demand in order to mitigate environmental impacts of energy use. According to a RE-intensive global energy supply scenario, up to 58% of the total global electricity generated in the year 2025 would be accounted by RE (hydro – 18%, biomass - 18%, and other renewables - 22%). According to the US Environmental Protection Agency scenario of 'rapidly changing world with stabilizing policies', primary biomass, hydroelectricity, and other primary renewables are expected to account for 39.6% of the global primary energy supplies in the year 2025. Although no energy scenario can be taken as an accurate prediction of the future, the above scenarios suggest that RE is expected to account for a very significant fraction of energy supplies in the not-too-distant future. If RE is to play its desired role, the educational programmes for producing the technical manpower required to make this possible must be established now.

Many countries around the world took initiatives for development and/or dissemination of RETs immediately after the first oil crisis of 1973. Except a few successful cases of the adoption of RETs, most of the efforts in this direction have not been fruitful. While the failures may be attributed to a variety of reasons, one of the inhibiting factors is the lack of a structured framework for providing energy education, in general, and REE (renewable energy education), in particular, to everyone, at all levels, and through all possible modes of education. For example, in many countries the lack of indigenous technology development capability in the area of new and renewable sources of energy resulted in the promotion of very expensive and inappropriate designs. Similarly, at some other places, owing to the non-availability of local technical manpower for proper repair and maintenance of the initially installed systems, the users decided to use some other energy resources and technologies. Some of the RETs were not accepted by the end-users as they were not properly exposed to the merits of these technologies. These and several other such cases are merely manifestations of the same root cause – the lack of proper REE. It is now widely accepted that REE should be included at various levels in schools, colleges, universities, and other academic institutions. In this connection the Department of Science and Technology, Government of India and the United Nations University, Japan are sponsoring a training programme on solar energy utilization for engineers and technicians from the developing countries. The programme is organised by the CNRSE (Centre for New and Renewable Sources of Energy), Anna University, Chennai.

The major objectives of the solar energy utilization training programme are to understand (1) the fundamentals of solar energy, (2) the theory and design/operational principles of solar energy devices, and (3) the limitations and environmental/economic aspects of solar energy technologies.

Programme

The general objective of the programme is to provide a commercially viable service in education, information, and training which is sensitive to market needs and national objectives.

Higher education in the field of solar energy is conducted for the period of nine months. The nine-month course includes theoretical lectures in plant training and project work. Energy centre researchers have written detailed manuals and reference materials, along with energy notes and other materials, that are used as textbooks in the courses. Courses are taught by staff members from the CNRSE and experts employed in the field of solar energy.

The course contents are:

- Heat transfer in energy systems
- Fundamentals
- Solar thermal systems
- Solar PV (photovoltaic) systems
- Renewable energy
- Excursions to solar energy fields/facilities
- In-plant training
- Project work

The detailed course contents are given below.

Heat transfer

The study of heat transfer is directed to the estimation of rate of flow of heat through the boundary of a system. Steady and transient conditions and the determination of temperature field under steady and transient conditions will provide the information about the gradient and time rate of change of temperature at various locations and time.

Fundamentals

- Solar radiation
- Solar constant
- Standard solar spectra

Solar thermal systems

- Solar collectors
- Solar hot water systems
- Solar refrigeration and air-conditioning
- Solar thermal storage
- Solar passive heating and cooling technologies
- Solar thermal power plants
- Solar pond

Solar photovoltaic systems

Photovoltaics are connected with the mentioned research activity and involve material science, electronics, and environmental engineering. The educational process includes lectures, laboratory work (training), and excursions to the PV RE facilities. The following is an example of a course on solar PV systems outline.

- PV device physics
- p-n junction solar cells
- Dark and illuminated characteristics
- Efficiency limits, losses, and measurements
- Standard silicon solar cell technology
- Improved silicon cell technology
- Design of solar cells
- Other device structures and PV materials
- PV modules, systems – components, sizing and applications
- Measurements and testing in PV
- Design of stand-alone and grid-connected PV systems
- Projects and PV plants in the world
- PV renewable energy – a strategy for the environment
- Accumulation and distribution of PV systems for energy efficiency/energy saving

Renewable energy

- Renewable energy – energy and the environment
- Wind energy technologies
- Geothermal technologies
- Mini-hydro energy
- Biomass energy

In addition to the above lecture classes, in-plant training and excursions are arranged for the participants to solar energy fields and facilities.

Project work

At the completion of the course the participants have to do the project work in the field of solar energy. Some of the project titles are listed below.

- Performance evaluation of PV operated water pumping systems for irrigation
- Lost cost technology for solar cell manufacturing
- Design of solar house
- Solar town planning
- Integrated (solar and wind) water pumping systems

Thapathali
Campus
Post Box No.280,
Ramshahpath
Kathmandu
Nepal

Riddhi Ratna Sthapit*, Pradeep Kaji Tamrakar

Syllabus design of rural technology course for technician diploma in mechanical engineering in Nepal

Renewable energy education: current scenario and future projections
pp. 113-119

Abstract

With a view to making the syllabus of the Diploma Course in General Mechanical Engineering more adapted to the needs of the country and improving employment prospects of graduates, the Thapathali Campus of the Tribhuvan University has conducted a study on the feasibility of running a course on Appropriate Technology. As a result of the Tracer study and feasibility study it has been felt that the interdisciplinary and comprehensive course on Rural Technology needs be incorporated into the curriculum of Diploma in Mechanical Engineering. This course deals with renewable energies, entrepreneurship, and communication aspects. The paper describes the rationale, objectives, outlines, and methodological aspects of the rural technology course.

---

*Author for correspondence

Introduction

The Thapathali Campus is one of the four campuses under the fold of the Institute of Engineering, Tribhuvan University, Nepal. One of the main objectives of the establishment of the Thapathali Campus was to produce technicians in mechanical engineering and automobile engineering. The present three-year course is divided into six semesters, the last semester being devoted to an elective course, where a student of General Mechanical Engineering can choose any one of the four electives, namely machining, welding and fabrication, plumbing and pumps, and plant maintenance and repair.

The broad objectives of the existing three-year course is to produce graduates who will be able to

- work completely in a wide range of production and repair and maintenance jobs in industries, using manuals and the related information;
- find and use technical manuals and information in the job;
- implement new technology/information as required by the industry;
- guide/demonstrate workers to carry out the given job;
- communicate the design of the engineer to the workers;
- cope with management and safety problems at the shop-floor level;
- establish and run small enterprises independently;
- qualify himself/herself for upgrading courses; and
- keep abreast of relevant technology by learning continuously on the job.

Rationale

Rural technology plays a vital role in the upliftment of the living and working standards, and quality of lives of the rural people. Renewable energy systems are considered to be some of the promising options to supply rural areas in Third World countries, including Nepal.

As per the tracer and feasibility studies, the campus graduates are mostly absorbed in urban areas and there is a shortage of middle-level technicians in rural areas.

Justification of the new course

The existing technician courses are based on city-oriented modern technologies.

The education on renewable energy and rural technology at the university level has not been developed so far in Nepal.

The proposed course on rural technology is the outcome of a series of workshops and seminars conducted at the Thapathali Campus and a number of tracer and inventory studies and feedback from ex-graduates.

Curriculum development cycle

Curriculum development is a continuous cyclic process based on the complexity of the entire process.

The curriculum development cycle comprises the following mutually related steps.

- Analyse the situation
- State the objectives
- Identify the target group
- Outline the course
- Identify constraints
- Design the course
- Implement the course
- Evaluate the course

Factors considered when analysing the situation for syllabus design

Socio-economic structure of the country

Nepal is one of the least developed countries in the world, with around 50% of its population living below the poverty line. About 90% of its people live in the rural areas.

Rural living condition

The rural living condition is described by the following factors (1) rural situation, (2) rural problems, (3) rural needs, and (4) rural potential.

Situation of rural technology

The following constraints are related to the development and promotion of rural technology (1) finance, (2) human resources, (3) R&D, (4) training, (5) information dissemination regarding rural technology, and (6) social and cultural constraints.

Technical education and training prospects

There are no formal educational institutions producing technicians in rural technology and renewable energies in Nepal. Short-term informal training on rural technology and renewable energies are being offered by many organizations, government as well as non-government organizations.

Employment prospects

Due to the lack of technical manpower, rural technology does not reach the local people to ease their burdens and help them conduct their daily life more efficiently.

The rural technology technicians are likely to find employment in the following organizations:

- academic institutions involved in technical education and training

- banks and financial institutions involved in rural technology development projects
- consulting agencies, and
- organizations, government as well as non-government, national as well as international, dealing with manufacture, maintenance and repair, R&D, installations, and applications of rural technology.

Curriculum of high school education

School-level science curriculum does not include energy concepts and information on rural technology.

Newly-revised diploma course

The new course in mechanical engineering is divided into six semesters.

Course features

- Interdisciplinary approach
- Comprehensive approach

Course setup

The diploma course in mechanical engineering comprises compulsory course and elective course. The compulsory course includes humanity subjects such as Nepali, English, and Nepal Parichaya, and natural science subjects such as physics, chemistry, and mathematics.

Technical subjects under this course include:

- Engineering drawing
- Material science
- Applied mechanics
- Strength of materials
- Machine element and mechanisms
- Thermodynamics and heat engines
- Hydraulics and hydraulic machines
- Electro technology
- Applied electronics
- Hydraulic and pneumatic control
- Computer applications
- Manufacturing technology
- Industrial management
- Public relation and personality development
- Industrial attachment
- Design and project work

The last three semesters are partially devoted to elective courses, one of which will be selected by the student. Rural technology is one of the elective courses.

Elective course on rural technology

The overall objective of the newly revised diploma course is to produce middle-level techno-managerial resource persons with good understanding of renewable energy and practical skills in the areas of technology, entrepreneurship, and rural communication skills. The specific objectives are outlined below.

- To create awareness about the importance of different type of renewable energy
- To provide basic knowledge of all viable renewable energy technologies
- Evaluate local development problem options by analysing a given situation
- Communicate with the rural communities
- Disseminate information in the field of communication, technology, and entrepreneurship
- Design simple technology and fabricate minor mechanical components of selected technologies
- Teach how to operate selected technological systems
- Estimate costs and impacts

Course components

This elective comprises three components: (1) rural technology, (2) business management and entrepreneurship, and (3) applied rural sociology.

The rural technology component comprises three basic parts: (1) Part I covers fundamental aspects, (2) Part II deals with applications, and (3) Part III includes specialization on one of the rural energy technologies. Students can choose from micro-hydro power technology, solar photovoltaics, solar thermal, and biomass and biogas.

Course outline of rural technology component

- Concept of renewable energy (solar, wind, water, biogas and biomass)
- Concept of rural technologies
- History of use of renewable energy and rural technology
- Basics of renewable energy technologies
- Applications of renewable energy in rural areas
- Design, fabrication, installation, maintenance, and repair aspects
- Economic analysis of technology systems

Course outline of business management and entrepreneurship component

- Entrepreneurship
- Business potentiality survey
- Business management

- Project
- Legal rules and facilities
- Fieldwork
- Business feasibility

Course outline of rural sociology component

- Introduction to applied rural sociology
- Rural society
- Rural institutions
- Modes of livelihood
- Rural resources
- Extension approach
- Communication
- Participation
- Technology transformations
- Concept of development
- Field exposure trip to different parts of Nepal

Teaching methods

- Lecture
- Tutorial
- Workshop practical
- Laboratory work
- Field visit
- Industrial orientation
- Industrial attachment

Assessment methods

- Case studies
- Seminars
- Group discussion
- Field placement
- Project work

Instruction materials

- Textbooks
- Reference books and periodicals
- Course manual
- Lab manual
- Workshop manual
- Slides
- Transparencies
- Audio-visual material

Course implementation

There are internal and external constraints to successful implementation of the course. Internal constraints include budget limitation, insufficient physical facilities, lack of training personnel, and inadequate instruction materials.

The external constraint is lack of awareness on renewable energy and rural technology among policy makers, guardians, and rural people.

Course evaluation Appropriateness of course contents, duration, and methodology and attainment of course objectives are to be considered when evaluating.

Conclusion

Technician level rural technology course is being introduced into the curricula of diploma level education. The curriculum needs regular revision and modification based on situation analysis, evaluation, design, and implementation factors. It is very essential to create awareness on rural technology and renewable energy in order to attain the stated objectives.

Acknowledgement
The authors would like to thank the Thapathali Campus for providing secretarial support for the publication of this paper.

TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi -
110 003
India

Shirish Sinha*, Dilip Singh

Energy education and capacity building of NGOs: TERI's experience

Renewable energy education: current scenario and future projections
pp. 120-132

Abstract

NGOs (non-governmental organizations) have been identified as the most effective agencies for the implementation of rural energy programmes. The process, however, has been hampered by various barriers like technological limitations and infrastructure issues, among many others. Capacity building or training is considered an important solution but any training programme should be viewed in the context of the realities that it can address. This paper is a synthesis of the experiences of the Rural Energy Group at TERI in conducting training programmes to give energy–environment education to the NGOs. The paper discusses the lessons that have been learnt from the feedback of the participants, identifies the requirements and needs of the NGOs, and proposes a structure or format for the training programmes.

---

*Author for correspondence

Introduction

The need for an environmentally sustainable path of development has been recognized globally. Providing energy in an economically efficient and environmentally benign way is a critical requirement for sustainable development. This is particularly relevant in the context of rapidly developing countries like India. For long, the fossil and biomass energy sources have dominated the energy supply system in India leading to a variety of environmental problems. RETs (renewable energy technologies) based on perennial sources of sunlight, water, wind, and biomass offer sustainable alternatives to mitigate these problems and lead the development process towards sustainability (Ramana 1998).

India has had an active renewable energy programme for over a decade during which a number of RETs based on biomass, solar, and wind resources have been disseminated (MNES 1998). The prominent technologies among them such as biogas plants, biomass gasifiers, improved cookstoves, and SPV (solar photovoltaic) systems, have been targeted mainly to meet rural energy requirements.

However, the impact of the renewable energy programme has been mixed, largely due to certain barriers. Some barriers involve technological limitations, while some others are operational and institutional problems in the implementation and adoption process (Ramana 1998). These barriers can be categorized as planning, technical, implementation, financial, capacity, and information barriers. In the past few years, there has been emphasis on addressing the planning, technical, implementation, and financial barriers through a series of programmes. However, the emphasis on the capacity and information barriers is very low.

Training - why it is essential

Training or capacity building has many definitions and wears many hats (Mrohs 1998). At TERI, we define *training* as a process of attaining minimum levels of knowledge and skills, so that specific tasks, appropriate to achieving desired goals, can be performed to measurable standards. Proper and adequate training for various interest groups involved in the implementation process and creating awareness among users on the functioning of various systems have not received any importance in most RET programmes. There have been several instances where a technology like biogas failed because the household was not told the ratio in which dung and water should be mixed for the feedstock. Or where an improved *chulha* consumed more fuel than a traditional *chulha* because the user did not know how to adjust the damper. While the omission of imparting such basic awareness has resulted in systems not working due to even minor problems (TERI 1998), the lack of rigorous training for the masons constructing biogas plants or *chulhas* has resulted in poor quality leading to system failure (TERI 1994, TERI 1997).

The NGOs and other local institutions in the rural areas have been involved in the dissemination of RETs under different programmes but their experience has remained limited to a single technology or a combination of technologies (TERI 1998a). The scope of activities remained rather limited to mere demonstration or promotion and installation in the case of a few technologies. Also, this approach of promotion of one technology or a combination of technologies did not have the desired effect on the overall energy situation in the area of activities of the NGOs. This was because the mandates of these organizations under these programmes were to disseminate technologies, rather than understanding how it influences the overall energy scenario and the local environment. Lack of awareness, information on new technologies, and modifications in the existing technologies among the NGOs and implementing agencies have resulted in low information dissemination even to the users of the systems.

It is essential that the NGOs are sensitized to rural energy issues, other RETs, their application and scope, and the concept of rural energy planning and implementation through a series of training programmes. This necessitates capacity building including training, awareness, hands-on training, etc. to be an important component of the rural energy planning process.

Capacity building of NGOs

Keeping to its objective of developing the skills and knowledge of NGOs involved in the rural areas, TERI initiated a series of training or capacity building programmes to develop the skills and knowledge of NGOs on rural energy planning and impart hands-on experience in the technologies and their implementation. TERI has been actively involved in the rural energy sector for more than a decade. Its experiences reflect lessons that it has learned as part of the work done with the local institutions and NGOs. TERI conducted a series of three programmes in 1997 for the capacity building of the AFPRO (Action for Food Production) network of NGOs. However, the need for developing such capabilities among the NGOs has been the focus of the group for quite some time. The need for such programmes was again felt when TERI started an implementation project covering the rural areas of Himachal Pradesh, Uttar Pradesh, and Rajasthan (TERI 1997).

TERI, through its projects on rural energy planning and evaluation of technologies and programmes, identified the kinds of problems that exist in the field. These problems, that either the users faced in managing the technologies or the local institutions involved in dissemination, formed the rationale for initiating these training programmes for the NGOs (TERI 1996, TERI 1997, TERI 1997a, Dutta et al.). Another factor was a shift within TERI from conducting energy planning studies to undertaking implementation of energy projects with the help of local institutions (TERI 1997). This meant that either we identify and work with only those NGOs which are already involved in dissemination of energy technologies or develop capacities of NGOs in our project areas. Box 1 gives the rationale for initiating training programmes.

Box 1 Rationale for initiating training programmes on rural energy

- Increasing need for decentralized energy planning
- Low awareness among users and implenting agencies
- Low degree of information sharing
- Limited technological information

Training programmes

NGOs have been involved in the implementation of various technologies, but the scope of their activities has remained limited to only technology promotion and installation. Also, in the case of most of the NGOs, the focus has been on promotion of one technology, whereas other interventions have been mainly in the form of demonstration. This approach did not have the desired effect on the overall energy situation in their area of activities. The other reason has been the limited information sharing between the NGOs and the users of the systems and a very limited understanding among the NGOs about the positive and negative impacts of the interventions. It has therefore been felt that the NGOs need to be sensitized about rural energy issues, other RETs – their application and scope, and, the concept of rural energy planning and implementation, through a series of training programmes.

In order to meet the said objectives, TERI conducted training programmes for the AFPRO network of NGOs between February 1997 and April 1997. These programmes focused on orienting the NGOs on relevant energy issues and programmes in the country. As a follow-up to this initial orientation process, another series of trainings was undertaken (January–May 1998), which focused on exercizing rural energy planning activities with the participant NGOs.

In order to develop the capabilities of NGOs in new and emerging technologies like solar photovoltaic, a separate programme was organized in June 1998 to provide orientatio to the network partners about this technology. Continuing i efforts of promoting environmentally benign energy solution in the north-eastern states of India, TERI organized a trainin programme in the mid-1998, to create awareness and develo the capabilities of NGOs working in this region on rural energy issues, RETs, and rural energy planning (Box 2).

The overall objective of all the training programmes that TERI organized was to involve the local NGOs in the planning process from the initial stage. The specific objectives of the training programmes were to:

- sensitize NGOs towards various rural energy and enviro mental issues in order to strengthen their ability to asse rural development needs;
- enhance the skills of NGOs to carry out decentralized energy planning with emphasis on integration with the ongoing development programmes, aided by systematically exposing the NGOs to various steps involved in th energy planning;
- assist NGOs in developing an operational energy intervention plan for implementation and integration of energy interventions with the ongoing development activities; and
- provide orientation in new and emerging technologies.

Box 2 Training programmes

- Capacity building on rural energy issues with AFPRO partners (three programmes in 1997)
- Institutional strengthening of Indian NGOs on rural energy planning (three programmes in 1998)
- Photovoltaic orientation (one programme in 1998)
- Training for NGOs in north-eastern states on rural energy (one programme in 1998)

Capacity building on rural energy issues

This training programme was conducted for AFPRO partne NGOs, and aimed to give them an overall orientation on th rural energy scenario in the country, and an overview of energy technologies and rural energy planning (TERI 1997 The programme was spread over five days, with participant spending one complete day in the collection of information from the village and presenting their findings to the group.

The participants were divided into different groups and each team was given a specific theme to collect information on.

Institutional strengthening of NGOs on rural energy planning

This training programme was an extension of the programme that TERI had organized for the AFPRO partner NGOs. It was designed using the feedback from the earlier programme. The objective of this programme was to equip the participating NGOs for undertaking rural energy planning. A week-long training programme was conducted for the NGO functionaries in identifying the appropriate tool and variables for collecting information, developing questionnaires, and making an energy intervention plan (TERI 1998a). The participants spent considerable time in a village and collected information on different themes. Analysis of this information helped prepare an intervention plan for the village. Most of the training on how to prepare an energy plan was given hands-on to the participants.

Photovoltaic orientation programme

A day-and-a-half-day programme was organized with support from REPSO-India (Renewable Energy Project Support Office) and AFPRO to sensitize NGOs on SPV technology. The participants were representatives from 21 NGOs from the states of Bihar, Haryana, Himachal Pradesh, Madhya Pradesh, Uttar Pradesh, and West Bengal. The objective of the programme was to sensitize the NGOs about the SPV systems – the concept, applications, government programmes, and the role that NGOs can play in the promotion of the technology (TERI 1998b). Besides this, lecture sessions on these topics, demonstrations by manufacturers, and a field visit to an SPV plant were also organized to facilitate the learning process.

Training programme for the NGOs in north-eastern states

The programme was organized with support from IREDA (Indian Renewable Energy Development Agency Limited) to sensitize NGOs working in the north-east about rural energy issues, RETs, and rural energy planning (TERI 1998c). This programme was similar to the first orientation programme organized by TERI. As most of the NGOs that participated had some experience of working on energy technologies, the programme was designed to be participatory, with more time allocated for discussions.

Lessons

Training indeed plays an important factor in successful implementation of rural energy programmes and technologies, but for the training to be successful, it must incorporate the NGOs' needs not just in terms of energy technology interventions, but also by linking them to the other developmental programmes. Box 3 highlights the lessons that TERI learned from these programmes.

Box 3 Lessons from the training programmes

There is:
- awareness of the energy issues, but lack of proper perspective
- awareness of alternative technology, but insufficient information transfer
- need for focused training on energy planning
- need to develop understanding of local level impact of energy intervention
- need for hands-on training on renewable energy technologies
- lack of adequate/proper information dissemination material

Lack of proper perspective

Although most NGOs were aware of the energy issues, there was a lack of proper perspective. Most of the NGOs were involved in the promotion and installation of biogas plants, and also in the demonstration of other technologies, but their area of work remained limited only to technology dissemination. And this again remained limited to the promotion of only one technology. What was lacking in their work operation was the perspective of integrating these programmes with other developmental programmes and planning for other interventions. Most of their programmes operated in isolation. The lack of proper perspective can be further explained with the example that although the NGOs were collecting livestock statistics at the household level, they collected this information only from the perspective of installing biogas plants, whereas additional information on the usage pattern of other energy fuels would have given them a broader understanding of the energy scenario and helped them plan for other interventions, if biogas was not suitable.

Insufficient information transfer

It was seen that most of the NGOs had some prior experience of working with RETs. But the technological information available with them was not sufficient. They were not equipped with the information on technological advances that have taken place and lessons that other NGOs have learnt from the dissemination of such technologies. For example, in the case of AFPRO partners, they all knew which NGOs were working with them on the biogas programme, but there was little sharing of information in terms of experience. Another problem is sharing of experience in making interventions with other technologies. For example, a few households in West Bengal wanted to have an additional switch (bed-switch) to be connected to their PV system, but the trained technician refused to do so, stating that this will affect the system performance (TERI 1998), whereas, any such additional provisions in PV systems do not affect system performance. This is an example where households demanded some additional features but could not obtain them due to lack of knowledge among the technicians.

Training on energy planning

The initial training programme with AFPRO partners clearly brought out a need for a detailed training programme on how to do energy planning. It was not that these NGOs were not equipped to collect information from the villages and the households. Their problem was how to use the information to prepare the energy plan. The second training programme (institutional strengthening) focused on enhancing the skills of the NGOs to develop rural energy plans. To facilitate the learning process, participants in these programmes prepared an energy plan for each of the villages.

Local impact of energy intervention

An overview of the rural energy issues was very useful for the participants, but what was required more by them was to gain an understanding of the impact these will have in the areas where these organizations are working. This is required mainly from the viewpoint of explaining the advantages of such interventions to the community and to have a holistic view of the energy intervention, especially understanding the impact on the local environment and ecology.

Hands-on training in renewable energy technologies

Most NGOs have been working on biogas, and they have developed expertise in this technology. However, their need is to enhance the skills of the functionaries for installation, repair, and maintenance of other RETs. For example in West Bengal, most of the solar lighting systems installed by the Ramakrishna Mission are functioning well, because the village workers are trained to install and provide up-front repair and maintenance of systems. A hands-on training, which takes care of how to install and repair and maintain the systems, is provided for all the technologies and thus will ensure a longer functionality of systems.

Inadequate material for information dissemination

This has been one of the major constraints in disseminating information not just to the NGOs, but also from the NGOs to the users of the technologies. There is very little sharing of information among the NGOs, as there are very few materials (like books, newsletters, and other sources) available to be widely circulated.

Capacity building of NGOs – what needs to be initiated

Training programmes are often seen as *ad hoc* activities with short-term objectives. At TERI, every time a new training programme was started, we built upon the experiences and feedback of our participants to either redesign or develop a new approach to disseminate information. Across the world, training programmes are often conceived and implemented in isolation and every time a new training programme is undertaken, 'reinventing of the wheel' in terms of objective, methodology, content, field activity, and other dimensions often happens. We developed a working relationship with AFPRO to tackle this problem and our initial three capacity building programmes were worked out in detail keeping in view the long-term results that AFPRO wanted.

The feedback from the first programme guided us to undertake programmes that develop the skills on energy planning. And when we designed the second programme, we ensured that TERI worked as a facilitator to these NGO participants, to understand how the information that they collect from the field can be used to develop comprehensive plans. A framework was given to them and they were taught how to put all the information they collected into a structured format and develop an energy intervention plan. Conducting an orientation programme only on PV technology was again done because both AFPRO and TERI identified PV as one of the most potential technologies and concluded that the NGOs can play an important role in their dissemination and commercialization.

With more and more experiences, we kept modifying the programme structure. When we started the training programme for NGOs in the north-east, we knew that it was for the first time that these NGOs would get a complete orientation into renewables. In order to facilitate the learning process, the programme was made participatory. One of the key reasons for the success of our programmes is the flexibility we provide in terms of programme structure and in terms of the language (a combination of English and Hindi) used for teaching and discussions. Box 4 brings out what needs to be done in the future to make these programmes more effective.

Information material

Although several training programmes are conducted by different agencies, there is still a gap in terms of adequate information material. In an effort to bridge this gap, we compiled information from different sources and resource persons for our first programme, which was then modified into a manual on technologies and rural energy planning, both in English and Hindi. As part of the PV orientation

Box 4 Training programmes - future direction

Information dissemination material
- Technology and applications

Candidates for training
- Planning (decision-makers)
- Planning, implementation, and monitoring (middle-level functionaries and field workers)
- Hands-on training (skilled technicians and village workers)

programme, we came out with a handy document, which covers all aspects of PV technology. The book – *From Sunlight to Electricity* – is a compilation of information that gives the readers an overall understanding of the PV sector in India, designs and applications of specific devices and related benefits, finance, and policies. The document also discusses the PV technology programme in India, the issues therein, and its future directions.

But these are very limited efforts and many more documents of this kind are required. There is much scope for improvement, especially the fact that the rural energy planning manual can be further modified and improved in terms of content. An important aspect, other than the content, is the language. These documents of good quality are initially required in both Hindi and English.

Candidates for training

Another important aspect for greater effectiveness of the training programme is to do with the candidates or participants of the programme. Training programmes build on the skills and knowledge that each participant brings to the programme. If the target candidates for the programme have the knowledge and experience, then they will be able to implement the new skills acquired in the programme.

Our experience so far has been of having a mixed group of participants. Some of the participants were chief functionaries (decision-makers in the NGO) while some were the village workers. There was a vast difference in terms of skills and knowledge of these participants. Based on the discussion with the participants and officials of AFPRO, and internal discussions at TERI, we feel that the training programmes needs classification not just at the subject level but also at the level of candidates. We propose that the nature of the programme for decision-makers should be planning and project management. For the field workers and middle-level functionaries, it should focus on planning, implementation, and monitoring. And for technicians and village workers, hands-on training on technologies should be conducted.

One target group should be only the decision-makers (mainly the chief functionaries) of the NGOs. The programme for these should focus more on project management, overview of technologies, environmental impacts, and developing intervention plans and linking them to other developmental projects. These programmes should be treated as training for trainers, as these participants would then provide training to their middle-level functionaries and field staff. These programmes should ideally have a duration of three days.

Another target group should be middle-level functionaries and field workers, who need to be trained not just in planning but also in implementation, monitoring, and evaluation of the socio-economic and technical impacts of the intervention. This staff in an NGO form the core group which carries out most of the activities, so these programmes have to be very comprehensive. These programmes can be of one week duration and should be conducted annually.

A third group that should be targeted, and is emerging as a prime candidate for training is that of the technicians (skilled or unskilled) and village workers. Targeting this group would be a very effective way of providing hand-on training to provide technical services to the users of the system. With the help of these training programmes, we would be effectively upgrading the skills of these technicians and workers, for sustained system performances. Training programmes like these need to be jointly coordinated by the manufacturers of these technologies, research institutions, and academic institutions. Depending upon the technology, the duration of these programmes will vary, but these need to be organized either on a quarterly or half-yearly basis in different regions. The most important feature would be to conduct these programmes in the local dialect.

Conclusion

Training programmes can indeed be an important factor in the implementation of rural energy projects. However, training programmes dealing with rural energy planning have been implemented without constant competence targets. Although a lot of inputs have gone into organizing these programmes, participants have looked at these programmes with a short-term objective. The problem of mixed-group participation is something which needs to be addressed not just by those who are conducting these programmes, but also by those NGOs for whom these programmes are being organized. The training programmes organized by TERI were funded by other organizations, which resulted in limited opportunity to select candidates. The participants need to be selected to maximize the impacts of training efforts. Another important aspect is to develop good quality and standard information manuals and books. These again have to be done in two languages – English and Hindi – to start with, and then in other local dialects. NGOs and their staff at different levels should be supported and encouraged to participate in these training programmes, because these organizations have a support network already in place and have already carved out an important niche in the community.

References

MNES. 1998
Annual report
New Delhi: Ministry of Non-conventional Energy Sources, Government of India. 110 pp.

Mrohs M. 1998
Training and photovoltaic rural electrification
Progress in Photovoltaics: Research and Applications (6): 307–313

Ramana P V. 1998
As if institutions matter: an assessment of renewable energy technologies in rural India
Enschede: University of Twente. 238 pp.

TERI. 1994
Socio-economic impact assessment study of Urjagram project
New Delhi: Tata Energy Research Institute. 64 pp.

TERI. 1996
Evaluation of renewable energy technologies implemented under North Eastern Council scheme
New Delhi: Tata Energy Research Institute. 107 pp.

TERI. 1997
Fuel substitution in the rural areas
New Delhi: Tata Energy Research Institute. 94 pp.

TERI. 1997a
Market development of solar home systems
TERI-ECN Collaborative Research Programme
New Delhi: Tata Energy Research Institute. 19 pp.

TERI. 1997
Biomass – the Indian NGO experience, edited by Dutta S, Rehman I M, Mahapatra P, Venkata Ramana
New Delhi: Tata Energy Research Institute. 144 pp.

TERI. 1997b
Capacity building of NGOs on rural energy issues
New Delhi: Tata Energy Research Institute. 11 pp.

TERI. 1998
Evaluation of solar home lighting systems in Sundarbans, West Bengal
New Delhi: Tata Energy Research Institute. 36 pp.

TERI. 1998a
Institutional strengthening of Indian NGOs on rural energy planning
New Delhi: Tata Energy Research Institute. 9 pp.

TERI. 1998b
PV orientation programme
New Delhi: Tata Energy Research Institute. 4 pp.

TERI. 1998c
Training programme for NGOs in the North-east on rural energy and renewable energy technologies
New Delhi: Tata Energy Research Institute. 6 pp.

Centre for Rural
Technology
P O Box 3628
Kathmandu
Nepal

Sama Shrestha

Teaching and training communities of Kathmandu Valley in the use of solar parabolic cookers

Renewable energy education: current scenario and future projections
pp. 133-143

Abstract

In Nepal, energy supply is one of the major problems for both urban and rural households. Increase in population, high rate of migration to cities, high fuel bills, environmental degradation, and unsafe drinking water have resulted in the keen interest from people of Kathmandu Valley in the use of solar energy.

The increasing number of tourists and trekkers are major sources of income and many locals are engaged in running hotels, lodges, and restaurants. This has enhanced the fuel demand. In order to meet this demand partially, the CRT (Centre for Rural Technology) initiated the promotion of SK–14, an advanced German-designed solar parabolic cooker, as an energy-saving device in early 1995.

This paper highlights the promotion and dissemination strategies and the efforts made by educational and health-related institutions. The technical and economic parameters, which have influenced the adoption of this technology in the Kathmandu Valley, are also mentioned. The issues and problems faced during its promotion and its future scope are discussed. Brief case studies are presented to illustrate the effects of solar cooking technologies at the educational, institutional, and household levels. Further, recent policy support and incentives provided by the government to promote the application of renewable energy especially for solar cookers are highlighted. Finally, recommendations and conclusions are made.

Nepal – a brief background

Nepal is a landlocked country. To the east, west, and south lies India and to the north, China. Hills and mountains are Nepal's main topographical characteristics and occupy about 75% of the total land mass. Ecologically, the country is divided into three major regions—the mountains, the hills, and the *terai* plain—with altitudes varying between 70 m and 8848 m above the sea level. The former two regions are sparsely populated, rural in nature, and with very limited development infrastructure as compared to the southern low-lying plains. Like many other developing countries, agriculture dominates the economy contributing about 40% to the overall GDP (gross domestic product) of Nepal and providing employment to more than 80% of the economically active population. Other major economic activities include small-scale industries and tourism (Economic Survey, 1997/98).

Nepal - selected indicators

- Area: 147 000 sq. km
- Population: 21 million (growth rate 2.4%)
- Gross national product per capita: US $208
- Main economic activities: agriculture, small-scale industries, tourism
- Exchange rate: Rs 68 to US $1
- Main energy sources: fuelwood and other biomass, hydropower, petroleum products, solar energy

Energy scenario

Hydropower, biomass, and other renewable resources constitute the major energy sources of Nepal. Although the country has a large hydro potential of about 83 000 MW (25% of it is considered technically feasible), only about 250 MW is presently utilized, meeting only 1% of the total energy requirements. Nepal has no proven significant deposit of fossil fuels such as oil and coal. Therefore, it relies heavily on traditional energy sources such as fuelwood (80%) and agricultural residues/animal waste (11%). Excessive fuelwood consumption has led to forest depletion and environmental degradation. About 8% of the commercial energy requirements are met from imported fossil fuels, at an expense of about 40% of the foreign exchange earnings. Only 1% of the total energy is met by electricity supply, which is limited to about 14% of the total population. At present, only four percent of the rural population has access to electricity. Nepal's per capita annual energy consumption is about 0.13 tonnes of oil equivalent (14.06 giga joules).

Over the years, Nepal has experienced a growing demand for both modern and traditional energy owing to the increasing population and diversification of economic activities. Demand for energy for households, industrial use, and tourism is increasing at a very fast pace. Nepal has high potential for harnessing solar energy. The average insolation is around 4.5 kWh/m^2/day, and the sunshine for about 300 days per year is sufficient for most small-scale applications. The monthly daily global solar radiation varies from 120 to 260 w/m^2 with the annual sunshine duration ranging from 1900 to 2500 hours (Rijal 1984). Figure 1 gives data of the average sunshine hours per day in 1995, 1996, and 1997.

In this context, application of RE (renewable energy) such as solar energy could play a major role in the overall energy scenario. However, this paper deals mainly with the use of solar parabolic cookers in meeting partial energy needs and the impacts of teaching and training the communities of Kathmandu Valley.

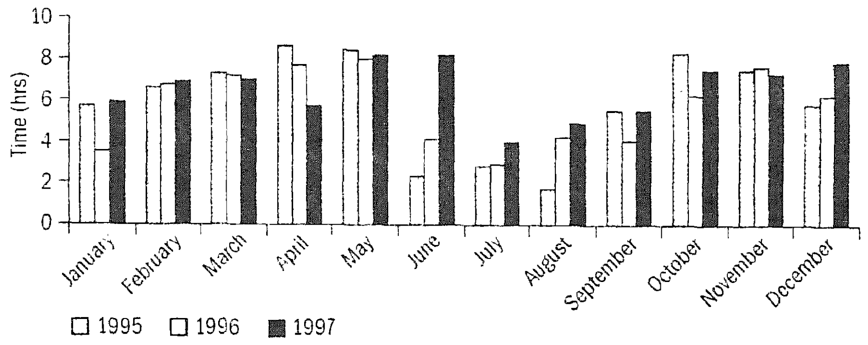


Figure 1 Average sunshine hours per day in 1995-97

Introduction

The source of cooking energy in Kathmandu Valley is a combination of wood, kerosene, LPG (liquefied petroleum gas), and electricity. The fast growing population and migration from rural areas to the valley has increased the demand for energy. This has resulted in increased fuel rates, fuel shortages, and power shortages. Most tap and well water is usually not safe to drink. Hence, a lot of fuel is consumed in boiling water. The increasing number of tourists and trekkers are now major sources of income and many locals are engaged in running hotels, lodges, restaurants, and tea shops resulting in an increasing demand for fuel.

Keeping in mind the increasing demand for energy, the environmental degradation, and health-related concerns, the CRT introduced solar cookers as a means of saving fuel, improving health conditions by pasteurizing water, and providing a smokeless environment.

CRT, with the help of various organizations including educational and health-related institutions, initiated the promotion of various types of solar cookers in 1992. The most popular solar cooker in the valley is the parabolic SK–14. But there are other designs which are used according to personal preference. For example, trekkers and campers use the backpack solar cooker as it is lightweight (Ligtenberg 1993). Outside the valley, solar box cookers are liked as they are economic and easy to transport. Recently, a new type of solar parabolic cooker, which can be folded, was introduced. Since it is lightweight and easy to transport it can be carried to the hills and mountains. CRT has promoted more than 2000 box cookers since 1993. Since 1995, it has been promoting the SK–14 vigorously. The cooker was initially imported from EG-Solar Germany. At present, only the highly reflective aluminium sheet weighing 3 kg comes from Germany. The manufacturing of cooking pots, fabrication of the outer frame, fitting of frames, etc. is done locally.

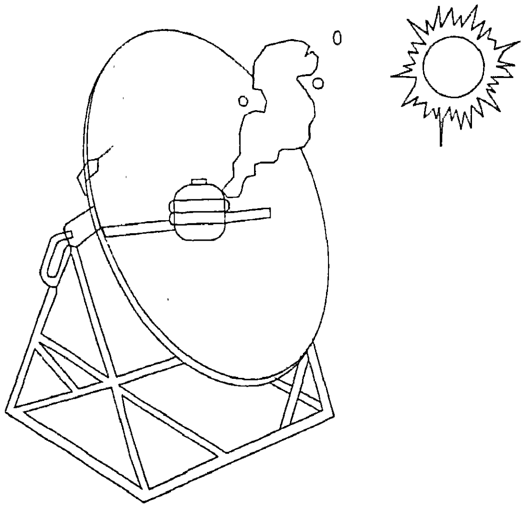
From CRT, about 82 solar parabolic cookers have been promoted in the Kathmandu Valley. After the government provided a 50% subsidy from the fiscal year 1998, the demand for the cookers is increasing gradually. Since February 1998 till date, 47 parabolic cookers have been promoted. At present, there are about 20 more buyers in the list waiting for their subsidy-grant process to be completed. The number of cookers is not yet big in itself but the remarkable fact is that people have started realizing their importance.

Solar parabolic cooker (SK–14)

This cooker's reflecting surface is in the form of a parabolic dish, which concentrates the solar rays at a focal point at which the black cooking pot is placed. The diameter is 1.4 m. The schematics of this cooker are shown in Figure 2.

It consists of lower and upper layer reflector panels made from highly reflective aluminium sheets. These aluminium sheets are fixed to a parabolic metal frame. The reflector is mounted in such a way that it can be easily adjusted towards the direction of the sun every 15–25 minutes. The total weight of a parabolic solar cooker is 20 kg. The aluminium reflector weighs 3 kg. At the bottom of the metal frame, four roller wheels are fitted which makes it easy to move around.

The net power of the cooker is approximately 600 W in good sunshine. Very high temperature (above 300 °C) is achieved in this cooker and the quantity of heat transmitted to



Parabolic solar cooker

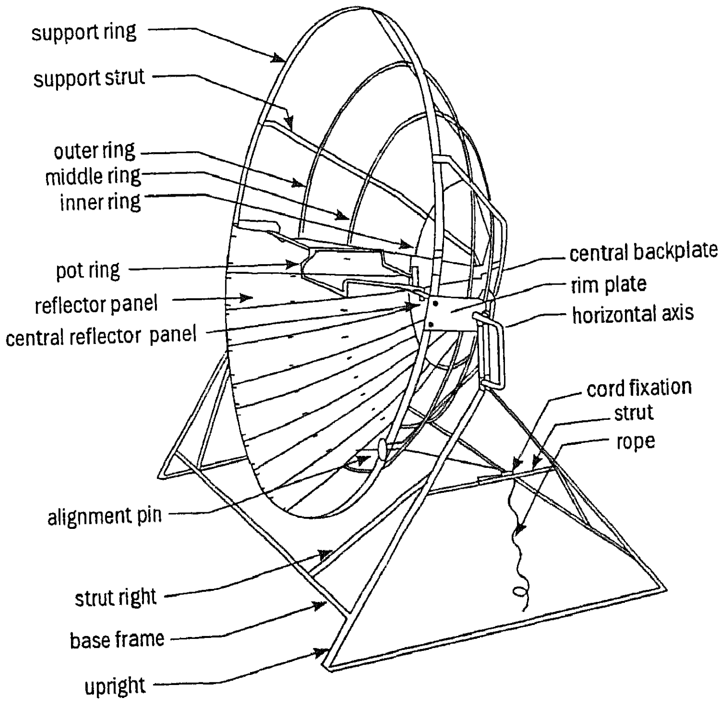


Figure 2 Schematics of the SK-14 solar parabolic cooker

the cooking pot is proportionate to the reflector area. Two litres of water on a sunny day (atmospheric temperature 24 °C) takes about 15 minutes to reach 100 °C. Almost every type of cooking such as boiling, frying, and baking, can be done in this cooker. Due to its deeply curved parabolic reflectors, the focal point lies inside the dish. This prevents accidental fires and injury to eyes. However, care should be taken while handling it.

Before removing the cooking pot, the reflector needs to be rotated away from the sunrays, leaving the pot in the shadows. With the help of an alignment pin, it is possible to ascertain if the sunrays are perfectly focused. In order to adjust this, it is necessary to position and move the parabolic dish in such a manner that the shadow of the alignment pin disappears. When the cookers are not in use, the reflector is turned upside down to protect it from rain, dust, and scratches. The operational instructions and safety rules are taught to the user and an operational manual is given along with the cooker.

Teaching and training

The following methods of teaching and training the communities of Kathmandu Valley were made for the effective promotion of the solar parabolic cooker.

Demonstration

CRT has conducted a number of public demonstrations and awareness campaigns on solar cooking technology. This has created a strong interest among the general population. Various solar-related demonstrations were organized at the following places and dates: Kirtipur, March 1992; Pharping, October 1992; Bhaktapur, April 1993; Dhulikhel, April 1993; Bhrikuti Mandup, June 1993; Bhaktapur, September 1993; Durbar Square, November 1993; Patan, April 1994; Patan, August 1996; Naubise, October 1997; Durbar Square, February 1998; Dolakha, September 1998; Blue Star Hotel, October 1998; CRT premises, December 1990, December 1991, March 1992, September 1992, November 1992, January 1993, December 1993 (CRT Reports 1997, 1998).

During the demonstrations, various food items were cooked in the solar cookers. People attending the demonstrations obtained practical information by observing the use of solar cookers. They observed the water pasteurization test, possible commercial uses, and cooking methods. They also got to taste the solar cooked food. Through brochures, handouts, posters, and promotional and training manuals, they gained theoretical knowledge as well. These demonstrations have also provided exposure to environmentalists, scientists, women entrepreneurs, and community leaders on solar cooking.

Educational 'nstitutions as promoters

Orientation on solar cookers given to a number of educational institutions has created interest among teachers and students. Information on solar cooking provided by CRT has encouraged students to develop their own study projects with innovative designs. This teaching approach was found to be effective and also helped them understand the importance of RE. Box 1 provides a case study to illustrate this point.

Similarly, students of Padma Kanya Campus, Siddhartha Banasthali High School, Vishwa Niketan High School, Engineering Campus, and Kathmandu University frequently get involved in solar cooking demonstrations and training activities as part of their educational course (CRT Report).

Box 1 Initiative by the students of St. Xavier's Campus, Kathmandu

Students of St. Xavier's Campus, Kathmandu, have formed a club known as Social Service, Environment, and Appropriate Technology. As a part of the science class assignment, they are encouraged to take up projects that are related to renewable energy technologies. They develop technology models to transform their theoretical knowledge to practical application. Every year, on graduation day, they exhibit different technology models including solar cookers. By building these models themselves, they get acquainted with various aspects of model building, scientific investigation, hypothesis formulation, research skills, and practical use. Through the exhibitions, they publicize the importance of using alternative and renewable energies among parents, students, and teachers of other faculties. This encouraged many parents, students, and teachers to use solar cookers at home.

Source Personal communication, October 1998.

On 17 October 1998, a Teachers' Workshop on Renewable Energy was held in Kathmandu. This workshop was organized by the NERL (National Education of Renewable Laboratory), US and AEPC (Alternative Energy Promotion Centre), Nepal.

The main objective of the workshop was to orient the teachers to the importance of RE and help them incorporate RE courses into the existing educational curriculum at the secondary school level. (NERL/AEPC 1998).

Involvement of health institutions

The LFN (Liver Foundation, Nepal) has been actively engaged in educating the public on the importance of drinking boiled/pasteurized water to combat water-borne diseases, especially Hepatitis E. However, many people still drink unboiled water to save fuel costs. To counter this, LFN has advocated the use of solar cookers for pasteurization of water to make it safe for drinking without the use of electricity, LPG, kerosene, or fuelwood (Shrestha S and Vishnu M 1997). The Dhulikhel Hospital also uses solar parabolic cookers for disinfecting surgical equipment and heating water needed in the hospital.

Government initiatives

His Majesty's Government of Nepal, understanding the need and interest shown by the public, made a policy to provide 50% subsidy on parabolic and box solar cookers since the fiscal year 1998. This policy is carried out through AEPC, Nepal. This present government policy has given high priority to the promotion and deployment of solar technologies.

Media, seminars, and workshops

A series of solar cooking technology seminars, workshops, and exhibitions for policy-makers, energy experts, personnel from different development and educational institutions, and users were held. Organizing these promotional and publicity activities was complemented by inviting the common masses to visit, through media such as newspapers, Nepal Television, and radio.

Training

A number of training programmes on solar cooking have been organized to aid the promotion of solar cookers. Training has mainly emphasized the concept of solar cooking, its advantages and disadvantages, fabrication, designs, possible commercial uses, small business entrepreneurship, operation and maintenance, safety measures, consumer feedback, and cultural and social barriers.

Use of solar parabolic cookers in the valley

The parabolic cooker is suitable for cooking most Nepalese dishes. Complicated dishes like *rajma* (kidney beans), *chapatis* (bread), patties, *chatamari* (pancake), vegetable curries, chilli chicken, popcorn, bread, etc., have been successfully prepared by the users. However, for cooking lentils, pressure cookers are used. It is very interesting to watch the cooker whistle. Parabolic solar cookers are used not only for cooking and baking but also for pasteurizing water and disinfecting surgical equipment. Some *ghee* (clarified butter) and oil shop holders use them to melt *ghee* (Monitoring Report 1998).

The valley survey showed that almost every household boils 15 litres of water on an average in parabolic cookers. The survey data showed that the parabolic cookers are used three hours on an average per sunny day. Cooking is mostly done on weekends. But some users prefer to cook daily for afternoon tiffin and evening *dal* (pulse). Due to the habit of taking lunch early in the morning, solar cookers are mostly not used for preparing the morning meal.

The cookers are mostly placed on the rooftop. Since most of the households in Kathmandu own a single house with an open space on the top and the kitchen on the top floor, the problems of space and difficulty in carrying food to the cooker were not found (Monitoring Report, 1998).

Most of the demand for is from the household level especially from relatives of solar cooker users. The users act as catalysts, encouraging other families to purchase solar cookers. The following case study (Box 2) highlights the saving in cooking fuel with the use of solar cookers (Monitoring Report 1998).

Box 2 How solar cookers help conserve fuel

Chandni Rajbhandari, resident of Devpatan, Kathmandu bought a parabolic cooker in April 1998 after she realized its advantages. She had seen the cooker being used so well in her relative, Shanti Shrestha's, home.

Chandni uses the solar cooker daily for boiling water. On weekends, she uses it to prepare rice, *dal*, meat curry, and vegetables and to boil eggs. Now she is happy because it takes about 45 minutes (on an average) to boil 10 litres of water on sunny days from which she is saving fuel (LPG).

Earlier, one LPG cylinder lasted only about 21 days but with parabolic cooker also in use now, it lasts for about 31 days. This shows that the gas can be used for an additional 10 days. Earlier, Chandni needed about 1.43 LPG cylinders per month which cost around Rs 664.95. Now, she needs only 0.97 cylinder per month, which costs Rs 451.05 per month. A saving of 0.46 (or 50%) of a gas cylinder corresponds to a saving of Rs 214 per month.

Chandni also owns a sweet shop. In order to prepare the sweets she needed about eight litres of kerosene every week. But now after using the solar parabolic cooker she saves about two litres. The cooker is also used to boil water and melt *ghee* required for the shop.

Chandni says that the solar-cooked food is tasty. She also says that she is advising her neighbours and friends to use solar cookers to save fuel and money.

Source Survey conducted by Kailash Sharma, CRT, August 1998.

Sociocultural barriers

In spite of the simplicity in the technology and its long-term cost effectiveness both in terms of investment and environmental benefits, the adoption by rural and urban communities has been slower than expected.

There are certain sociocultural sensitivities and factors which directly or indirectly hinder the widespread acceptance and promotion of solar cookers. The cultural barriers are more difficult than the technical ones in solar cooker dissemination. The traditional cooking methods and space requirement for placing the cooker also greatly influence the acceptance levels.

A change in cooking methods necessitates minor adjustments in eating habits as well, and habits can be very difficult to change. The superstition of not cooking in the open as the 'evil eye' can fall while cooking makes people reluctant to accept solar cookers. Extensive use of solar cookers is restricted as the cookers cannot be used during the monsoon, cloudy days, early mornings, and evenings.

The author recommends

- Habits are very difficult to change in old age. So the use of solar cookers has the best chance of becoming a lifelong habit if learnt at the school level.
- With effective R&D efforts and proper dissemination approaches, solar cookers will have an important role in minimizing the use of fuelwood, kerosene, and other non-renewable energy sources.
- Owners of hotels, restaurants, inns, and lodges should be encouraged to use parabolic cookers to pasteurize water and prepare special solar-cooked dishes.
- Development organizations and educational institutions could help to promote solar cookers in their project areas.
- Solar cooking should be integrated with other energy-saving devices.
- Follow-up, monitoring, and market studies should be regularly undertaken to obtain the expectations, opinions, and suggestions of users.
- A solar cooker which is technically mature, cost-efficient, and durable will have more possibilities of being accepted by the target groups.

Conclusion

Till the end of 1996, promotion of solar cookers had been low and the number of families using them was very little. However, the interest in solar cooking and its use have gradually increased from 1997 with the active involvement of various institutions including educational and promotional organisations. Some colleges introduced solar cooking as a means of science teaching. The government's support and subsidy incentives, public demonstrations as well as support by international experts have also played a very strong role in the promotion of solar cookers. Given this scenario, further emphasis should be given to a strong promotional and educational campaign and enhanced production facilities linked with market mechanisms for widespread adoption of solar parabolic cookers in urban and rural areas.

References

Economic survey of fiscal year 1997/98
Kathmandu: Ministry of Finance, His Majesty's Government of Nepal.

Rijal, K. 1984.
Availability of Solar Energy in Nepal
Kathmandu: Water and Energy Commission Secretariat.

Nepal Meteorological Service. 1997
Sunshine Hours
Kathmandu: His Majesty's Government of Nepal.

Ligtenberg A. 1993
Solar Trekking and other Dissemination Strategies: experiences in Nepal
California: Friendly Appropriate Solar Technologies.

Centre for Rural Technology. 1997
Report on solar energy demonstration at Durbar Square, Kathmandu
Kathmandu: CRT

Shrestha S, Vishnu M. 1997
Water Pasteurization with Solar Energy
In *Proceedings of The Workshop on Viral Hepatitis, 1997*
Kathmandu: Liver Foundation Nepal.

Centre for Rural Technology. 1998
Monitoring Report on Dissemination of Solar Cookers in Kathmandu Valley, 1998
Kathmandu: CRT

Acknowledgements

I would like to express my sincere thanks to Mr Ganesh Ram Shrestha (Executive Director, CRT), Mr Lumin Kumar Shrestha (Director, CRT), Mr Allart Ligtenberg (Solar Cooker Expert, Friendly Appropriate Solar Technology, USA), Mr Rajiv Munakami (Engineer, CRT), and Mr Brett White (Hunter Renewable Industries Cluster Group, Australia) for providing me valuable information and suggestions in preparing this paper.

Centre for Energy Studies,
Indian Institute of Technology,
Hauz Khas
New Delhi - 110 016
India

Subodh Kumar

Renewable energy education and training for integrated rural development

Renewable energy education: current scenario and future projections
pp. 144-153

Abstract

Renewable energy education and training is one of the most important prerequisites in the successful implementation of decentralized planning. The Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development in Bakoli, Delhi has been imparting RE (renewable energy) education and training to people at different levels. The paper highlights the need for RE education and training for integrated rural development and describes the activities carried out at the Institute in the field of education, training, and energy-related research.

Introduction

Despite the rapid economic development and technological advancement India has witnessed in the past few decades, a major part of the country's rural areas continues to be in a state of poverty. Only privileged classes comprising industrialists, traders, moneylenders, and rich farmers have benefited. An overwhelming proportion of the rural energy requirements in the household sector is still met from the traditional biomass fuels such as fuelwood, animal residues, and crop residues. This sector remains the most prominent energy consumer (about 75%) followed by the agricultural, industrial, and transportation sectors. Among commercial fuels, only kerosene is being used for lighting. The economic consequences of deforestation and reduced fuelwood supply due to large-scale usage of biomass fuels are that fuelwood has become expensive and that those who cannot afford the higher cost have to spend more time on fuel collection. The vast majority of rural households, especially the poorer sections, find themselves being subjected to increased stress and strain for procuring fuel to meet their basic energy needs.

Energy for rural development

Energy plays a significant role in economic development, technological advancement, and the welfare of human beings in any country. Energy consumption per capita is one of the important indicators of economic development. The increased use of fast depleting commercial fuels such as oil, coal, etc., in spite of their inherent benefits, pollutes the environment with poisonous gases in addition to putting an extra burden on the already scarce reserves of foreign exchange. Moreover, these energy sources are either not available in rural areas or available at prices not affordable by poor rural masses. Thus the problem of adequate supply of energy for households in the rural areas is much more acute than in urban areas. Moreover, inaccessibility of conventional grid and losses in transmission and distribution have constrained rural electrification. The power sector, therefore, caters mainly to agriculture, industrial, and urban needs. Rural areas are thus deprived of energy required not only for fulfilling basic needs but also for productive uses. There is thus considerable disparity in domestic energy availability between rural and urban India. The quality of life in rural India can be further improved if agricultural and rural industrial productivity is improved, population growth is stabilized, income levels are raised, and access of women to education and health services is improved. Recognizing the complex and multi-dimensional nature of the problems in rural development, an integrated and decentralized approach has been proposed.

The area-based IREP (integrated rural energy planning programme) serves precisely this purpose. The IREP envisages energy planning at the block level. Objectives of the IREP under the Eighth Five-Year Plan included the provision of energy for meeting the basic rural energy needs of cooking, heating, and lighting using locally available RE (renewable energy) resources and provision of energy for economic development of rural areas.

Renewable energy promotion programmes in India

The concept that decentralized energy systems are the answer to our rural energy needs both in the household and agro-industrial sector is now an accepted fact. The utilization of RE sources especially to meet rural energy requirements has been accorded high priority in government energy programmes since 1983. India is at present the only country with a full-fledged ministry – the MNES (Ministry of Non-Conventional Energy Sources). The ministry's SEC (Solar Energy Centre) provides testing facility for RES (renewable energy systems) to maintain their quality of standard. The IREDA (Indian Renewable Energy Development Agency) under the ministry's administrative control is perhaps the only dedicated financing agency involved in commercialization and information dissemination of RETs (renewable energy technologies) especially in the rural areas. Almost all the states in the country have their own state-level nodal RE agencies. These regional centres act as intermediaries/coordinators between government and people in formulating, implementing, and monitoring village energy plans. India is considered an advanced manufacturer of various RE devices, including solar thermal and photovoltaic systems, wind turbines, and small hydro. As a result of these continuous and vigorous efforts by the government, a variety of RES have reached the stage of technological maturity and economic viability for a wide range of applications.

Need for renewable energy education and training

Education and training are powerful means of meeting the fast changing demands and expectations of the society. Energy education is basically interdisciplinary and application specific. It requires understanding and knowledge of social, physical, and technical sciences. An acute shortage of people specifically trained and qualified in this discipline has been felt in industries, universities, and government departments.

During the last decade, the demand for RET equipment has been steadily growing and its usage has been spreading in almost all parts of the country. But the overall impact of RE programmes has been limited compared to the magnitude of rural energy requirements. Lack of awareness among the people especially in the rural areas remains a major factor holding back the usage of these technologies on a mass scale. Training of personnel is one of the most important prerequisites in the successful implementation of decentralized planning. There is an urgent need for involving more and more people at all levels in the education and training programmes to generate sufficient demand for RES. Graduate engineers must be trained in design, development, and dissemination of these technologies. The students in Industrial Technical Institutes are required to be trained as technicians in installation, maintenance, and repair of RES.

MGIIREPD's role in education and training

The IREP is aimed at human resource development (education, training, skill upgrading, retention, and utilization) at local, district, state, and regional levels for the implementation of rural energy programmes. In 1992, the MGIIREPD (Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development) was set up as a National Training-cum-R&D Centre in Delhi (Bakoli, Alipur Block) for providing education, training, and planning support to enable effective implementation of IREP programmes.

There are five major existing levels of formal and informal education and training programmes at the institute. These are

1. Postgraduate Diploma Programme in Rural Energy Technology,
2. IREP Personnel Training Programme,
3. Community Training Programme,
4. Training Programme for Educated Unemployed Rural Youth, and
5. R&D and workshop/seminar activities.

The details of various activities of the institute during 1992–97 are given in Annexure 1.

Plans are underway to start a new academic course leading to an MBA degree in Energy Management very soon to cater to the needs of energy-conscious industries in the proper management of conventional/non-conventional energy sources.

Postgraduate Diploma Programme

The postgraduate diploma in Rural Energy Technology having two semesters was started in 1994. Admission to the programme was made on the basis of an all-India competitive examination, called GATE. Engineering graduates who have secured a first class in specified disciplines are eligible for admission. The course is designed to include the various

RETs, energy research methodologies, integrated energy planning and economics, operational research in energy systems, etc. More emphasis is laid on laboratory work and R&D activities which are intended to give confidence to the students to work independently in the field of design/development of rural energy systems in research institutions. The dissertation project needs to be carried out by each student during the second semester as a partial fulfilment for the award of diploma. This project must include studies in some areas involving problems in rural energy. The details of the programmes are listed in Annexure 2. The main objectives of the course are listed below.

- To create qualified and trained manpower base in the country for sustainable rural development through the use of RETs.
- To familiarize the students with the design, development, and installation of RES and to develop careers in the emerging field.
- To impart knowledge to make informal and rational judgements on energy matters and prepare students for any energy-related assignments in R&D organizations, industries, and in government departments.

IREP Personnel Training Programme

Organizing training programmes for IREP personnel including junior engineers, project engineers/officers, project directors, etc., involved directly or indirectly in the implementation of rural energy programmes throughout the country has been the major activity of the Institute since 1992 (Annexure 1). Experience has shown that the training programmes should be organized frequently so that the officers at lower levels can be trained locally. The period of training may vary from one to three weeks depending on the level of officers for whom the programme is planned. Organizing a large number of short-term training programmes helps in updating the knowledge of engineers and scientists engaged in rural development activities.

Community Training Programme

To foster the development of energy services in rural areas, the participation of local communities is crucial since it is their full involvement in the rural energy programmes that can yield the desired results. Local community participation especially of women and school-going children in awareness programmes has a far reaching impact in popularizing the installation and utilization of various RE devices in the society. Women can be powerful as agents of change and motivators to conserve energy not only in their homes but also in public places. Studies have shown that housewives' attitudes towards conservation and their eco-consciousness have a positive impact on household energy consumption.

To create public awareness about the judicious use of the fast depleting commercial fuels and speedy adoption of RE devices, especially among the rural women and school-going children, the Institute initiated non-formal community education and training programmes in 1992 (Annexure 1). Women from nearby villages who are very often free after 11.00 a.m are called to attend these awareness programmes twice a week. The importance of RE devices, stressing the economy of money and energy nutritional aspects, and prevention of environmental pollution and health hazards caused by fuels and ill-designed cookstoves are discussed. During the programme, a visit to the Institute's Energy Park and Community Exhibition Hall, where working RES, video films on energy, etc., are shown, helps in spreading the message of efficient use of energy resources and provides answers to all rural energy problems. At the end of the programme, a question–answer session is arranged, where participants can clear their doubts with faculty. The main objectives of the programme are listed below.

- Inform and educate people that RE sources cannot replace conventional energy sources but can only supplement it.
- Familiarize participants with the various RES, their application, energy saving achieved, and advantages of their use in social, economical, and environmental perspectives.
- Conserve and optimize the use of fuelwood by using efficient improved *chulhas* in the rural areas.
- Create awareness for better understanding and speedy adoption of RES by the people at large.
- Provide information on the various government incentives and financial schemes.
- Discuss practical issues relating to the barriers for adoption of RE systems.

Training Programme for Educated Unemployed Rural Youth

The Programme was initiated at the Institute in 1995 with financial support from the Community Polytechnic, New Delhi, under the government's rural development programme. The duration of the training is six months. The main objective of the programme is to equip the rural youth with technical skills to enable them to take up self-employment in the fields of repair and maintenance of RES. It also provides them with first hand exposure to the basic concepts and applications of

RES. It has been a constant endeavour of the Institute to encourage the participation of fairly large number of youth belonging to weaker communities including scheduled castes, scheduled tribes, and other backward classes. Training at this level is confined mainly to imparting a variety of general skills rather than proficiency in any specific field. However, emphasis is laid on practical training to give them confidence to work with their own hands. The details of the programme are given in Annexure 3.

R&D and workshop/seminar activities

R&D activities at the Institute are oriented towards solving energy problems of the rural people by utilizing locally available resources in order to bring about social and economic improvements in their lifestyle. The activities are centred around sponsored projects. The research project 'Design and Development of an Expander for Conversion of IC Engine into Steam Engine and to utilize it as Hybrid Power Plant' sponsored by the Indian Agricultural Research Institute, New Delhi is in progress. In addition, several other sponsored programmes at the national and international level on energy-related topics have been organized at the Institute since 1992 (Annexure 1).

Conclusion

It has been realized, in recent years, that for effective implementation of RETs, the country not only requires widespread awareness but also the development of technical capability for the installation, operation, and maintenance of RE technologies/devices. Emphasis must be laid on human resource development without which maximum advantage cannot be obtained from the physical capital and other resources. To fulfil these needs, MGIIREPD has been striving hard at the national level to educate and train people from different levels in rural energy technologies with the objective of achieving rapid integrated rural development.

Acknowledgement
The author is grateful to the Director, MGIIREPD, Bakoli for providing valuable information and guidance from time to time.

Annexure 1

Institute's activities during 1992–97

Year	Name of the activity	No. of trainings, workshop, seminars organized	No. of trainees
1992/93	National training programmes	22	209
	Community training programmes	17	556
	Artisan training programmes	02	017
1993/94	National training programmes	17	154
	Community training programmes	19	763
	International workshop	01	125
1994/95	National training programmes	12	105
	Community training programmes	48	2345
	Seminars	01	
	Postgraduate diploma in rural energy technology		09
1995/96	National training programmes	06	
	Community training programmes	26	1188
	Artisan training programmes	01	06
	Certificate course on repair and maintenance of non-conventional energy appliances	01	15
	Seminars	01	100
	Postgraduate diploma in rural energy technology	10	
1996/97	National training programmes	05	68
	Community training programmes	17	725
	Seminars	01	100
	Postgraduate diploma in rural energy technology	10	
1997/98	National training programmes	16	90
	Community training programmes	45	725
	Seminars	02	100
	Sponsored training programme		
	Training	02	23
	National workshop	01	43
	Postgraduate diploma in rural energy technology	07	
	Certificate course on welding and repairing of non-conventional energy appliances	01	25

Annexure 2

Postgraduate diploma in Rural Energy Technology

[approved by the All India Council of Technical Education]

Duration: 1 year (2 semesters)

Admission to the PG Diploma programme is made on the basis of merit.

Minimum qualifications required
- BE/B.Tech. in Mechanical/Civil/Electrical/Chemical/Agricultural Engineering
- M. Sc. (Physics) with minimum 60% marks and valid score in GATE (a national-level examination)

All the students admitted are eligible for scholarship as per AICTE norms and are provided hostel facilities in the Institute's campus.

Credit system and awards of grades

Each course has a certain number of credits which describe its weightage. A student's performance is measured by the number of credits that he/she has completed satisfactorily. A minimum grade point average is required to maintain satisfactory progress. The grade awarded to a student will be based on his/her performance in minor and major tests, tutorials, laboratory work, home assignments, etc.

Course contents

Semester I		Credit hours
ES 520	Energy, ecology, and environment	3
ES 551	Energy resources and their utilization	3
ES 561	Rural energy technology I	3
ES 562	Rural energy technology Laboratory I	2
ES 542	Computer programming and simulation of energy systems	3
ES 511	Energy research methodologies	2
ES 572	Seminar	1
Semester II		
ES 531	Integrated energy planning and economics	4
ES 532	Energy conservation and management	3
ES 541	Operations research in energy systems	2
ES 563	Rural energy technology II	3
ES 564	Rural energy technology Laboratory II	2
ES 552	Instrumentation techniques in energy systems	2
ES 553	Instrumentation laboratory	2
ES 571	Project (experimental)	6
ES 573	Seminar	1

Annexure 3

Certificate Course in Welding and Repair of Non-Conventional Energy Appliances

[Sponsored Training Programme by the
Community Polytechnic, Delhi]

Duration: 6 months
Eligibility for admission: 8th standard pass

Course contents

1. Introduction to different workshop tools and operation of various workshop machines – lathes, sheet metal, grinding, and drilling. Knowledge of different welding techniques. Basic practical concepts on non-conventional energy appliances – solar cooker, solar dryer, solar water heater, and solar photovoltaic systems such as lantern, street lighting, water pumps, etc. Biogas and gasifier technologies, improved *chulhas* and construction details.

2. Practical sessions on repair and maintenance of the above mentioned non-conventional energy appliances.

3. Field visits/educational tours which include live demonstration of the above technologies.

CRICYT
Mendoza
PO Box 131 (5500)
Mendoza
Argentina

Jorge Mitchell*, Margarita Gascón

Teaching peasants how to build more energy-efficient houses

Renewable energy education: current scenario and future projections
pp. 154-164

Abstract

Junin in Mendoza, Argentina, is a rural area mostly devoted to vineyards and the production of vegetables for the local market. Most of the population, therefore, makes its living working on the farms. In the context of a Third World country, this implies that rural workers do not earn enough money so as to be able to pay for an expert when they build their houses. Most often, national, provincial, and even local governments have to provide environment in terms of energy efficiency suitable to the respective urban locations. During the last decade, the situation has been worsening due to adjustments in the government budget imposed by international financial institutions. Social programmes have been cut off and the shortage of money for helping the poor has resulted in sharp reduction of housing programmes for rural areas.

To alleviate this situation, poor peasants have organized NGOs (non-governmental organizations) with the purpose of building their houses. The municipality of Junin has been aware of the necessity of helping them not only financially, but also by making some arrangements with experts at CRICYT, the local Centre for Scientific Research. The authors are working as honorary members on a project transferring state-of-the-art, energy-efficient designs and teaching peasants the possibilities of using passive solar energy devices without increasing the cost of construction, or at least keeping it at the lowest possible level. The paper explains the challenges of organizing such workshops for rural workers at the NGO Calle Caballero.

---

* Author for correspondence

Introduction

In order to improve the quality of life of peasants in Third World countries, it is crucial to pay particular attention to their houses which are not very energy efficient. The traditional techniques of construction used to take into account the local weather, environment, and some very basic principles of orientation. Unfortunately, old rural houses in Mendoza were built in big mud sun bricks (the so-called adobones) which came under fire during this century as being insecure material for Mendoza, a seismic region.

In fact, from the beginning of this century, adobe construction has been banned in urban areas and discarded in rural ones. Therefore, this ancient technique that could have been improved with time (as in First World countries) was instead left to decay in our country.

The legislation against adobe construction, however, was far from effective. As a matter of fact, adobe houses are cheaper and poor peasants had very few alternatives when urged by the necessity of a shelter. Although adobe houses are prohibited and do not bear value for the real estate market, the poor build them without the appròpriate technology. The result is very low quality of most of the local adobe houses.

From another perspective, rural people have to apply for government loans for covering construction costs. The government, of course, has a leading role both in controlling and funding social housing programmes. In Argentina, as in many other Third World countries, national, provincial, and even municipal governments, have all provided an ever-increasing part of the society with social housing programmes. From the 1980s, however, due to the adjustments in the government budget imposed by international financial institutions, most social programmes have been terminated and the shortage of money for helping the poor has resulted in sharp reduction of housing programmes for rural areas. According to an official estimate, Junin, for example, can only help to build 90 houses every year.

Another set of problems derives from the tendency of providing the same design to everyone in the country, regardless of local weather. Needless to say, such a policy makes for low quality of thermal comfort in most of the houses built under government control or its financial assistance.

The office currently in charge of funding social housing programmes is FONAVI (Fondo Nacional de Vivienda – National Social Housing Fund). It administers a budget of around US $900 million yearly. Mendoza receives 4% of that figure, but the province increases its budget for social housing programmes with money coming from different taxes and levies, and the monthly instalments paid by previous FONAVI credit beneficiaries[1]. According to our estimate, only 20% of the much needed social housing can be built with that budget: 4000 houses of 50 square metres each.

Although it is better to have a small house than none at all, complaints about limited space and lack of thermal comfort have had a rather negative impact on the rest of the society. Beneficiaries of FONAVI loans are not satisfied, and neither is the rest of the society.

Nevertheless, the undeniable fact is that FONAVI houses are not energy efficient. The problem is that any attempt to improve them has to ensure that the overall cost is kept to a low level. Another less evident fact is that inefficient houses are expensive to heat and cool. The poor, however, both in rural and urban areas, prefer to keep things just as they are, simply because they cannot afford the costs of improving the thermal comfort of their houses by consuming fuel or gas.

Available data shows that houses built in cities under FONAVI programmes are inefficient in the use of energy. And they usually become still more inefficient in rural areas. Figure 1 shows the average temperature during winter in rural areas like Junin.

In 1998, the authors offered help to peasants in Junin during the process of designing more energy-efficient houses before applying for a FONAVI and municipality loan. It was the first experience in Mendoza of transferring scientific knowledge about passive solar energy to rural people who cannot afford to pay an expert.

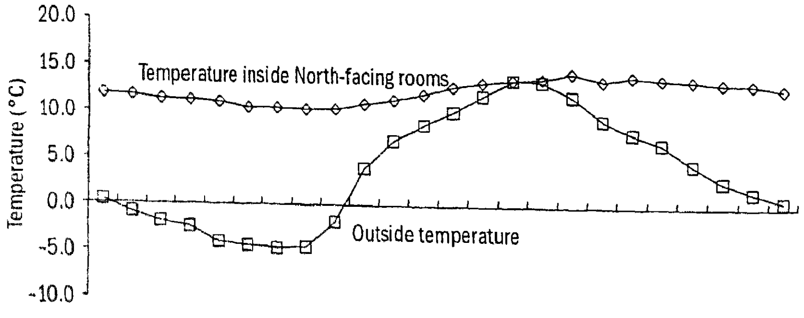


Figure 1 Average temperature for winter in rural area - Mendoza

---

[1] Law 24464 regulates the administration of FONAVI, prohibiting the use of the funds to build anything but social houses.

Junin in Mendoza is a rural area with 28 418 inhabitants. Vineyards and small-sized farms (6.6 hectares) are devoted to the production of vegetables sold in the local market. Agro-businesses are also related to the limited agricultural production. Most people, therefore, make their livings either working on farms or at a factory.

Rural incomes are as low as US $64 per capita for a family of five members. This was the size of rural families who attended our workshops and whose financial capacity was limited. To put figures into perspective, a FONAVI loan is US $15 000 per family, and it finances the building of merely 80% of a small house of 50 sq.m. Also, according to FONAVI regulations, one of the requirements is that families have to own their plots. Some other restrictions, dealing with construction materials, increase the overall cost of the house.

As above data shows, peasants and low-income workers earn US $300 or less per month, which is not enough money to pay for an expert opinion. Some peasants, upon receiving a loan, try to build their houses by applying a few building techniques known by tradition. Others prefer to join a cooperative and let constructors work according to their plans.

To alleviate the financial difficulties of building a house with a mere US $15 000 and, simultaneously to improve the quality of their houses, peasants began to organize themselves into NGOs with the purpose of buying land and materials and also building the houses. The municipality of Junin has been aware of the necessity of helping them, not only financially, but also by facilitating arrangements with experts. At CRICYT, the authors worked on an honorary basis on a project of transferring state-of-the-art energy-efficient designs to peasants. Workshops were implemented with the purpose of teaching peasants the possibilities of applying passive solar energy principles to their designs without increasing the cost of construction, or at least keeping it at the lowest possible level.

Workshops: efficient tools for solar energy education

One basic question during social work has always been how to approach poor people without patronizing them. In parallel, our question was how to encourage them to participate in the entire process of designing their houses. When we first met with the peasants of Calle Caballero, we understood the challenges we would face during the transference of state-of-the-art designs of energy-efficient houses.

Early in 1998, peasants and rural workers organized themselves into the NGO Calle Caballero to combine both their efforts and their savings to buy a big track of land, and to prepare the layouts for a rural neighbourhood in Junin, where they could perform part of their rural activities properly.

As mentioned earlier, to receive financial assistance from the municipality of Junin and FONAVI, this NGO needed to fulfil some requirements like the legal property of the land and the appropriate designs for the houses. At this point, they had the option of copying one of the FONAVI designs. Nevertheless, they knew what this would mean in terms of thermal comfort and space. Instead, they accepted our free help in the workshops. We would transfer state-of-the-art knowledge of passive solar construction and, at the same time, they would be allowed to talk about their needs.

The Municipality of Junin agreed to this open strategy because the earlier year, the money for social programmes from the national government, including money for social housing programmes, was not given to the municipality simply because it did not have all the requested paperwork ready. Unable to help Calle Caballero with designs for the houses that these people wanted (or needed), the municipality accepted Jorge Mitchell's offer of organizing workshops to come up with appropriate designs.

We organized workshops with the goal of imparting very simple concepts of passive solar houses to people who could hardly read since most of them had attended only elementary school. No written material was used; all the information had to be transformed into graphics, maps, etc.

Also, peasants do not have too much time as rural work is time-consuming. Many peasants had to walk or bike for several kilometres to the school or house where the workshops were held. Moreover, workshops were held in late evenings during the fall of 1998. Nevertheless, the evidence that a house is a long-lasting, strong desire of any human being was there for all to see when a mother with her infant once arrived all wet after biking in the rain for almost an hour. Examples of this kind have been abundant and are etched clearly in our minds. Also, it is remarkable how people become involved when they start to understand how to improve their quality of life by building better, energy-efficient houses.

During the workshops, we proceeded to demonstrate the value of keeping in mind the elements of:

1. local weather,
2. orientation,
3. site layout,
4. solar control devices,
5. insulation, and
6. ventilation.

The bottom line was to keep the costs to the lowest possible level. Any increase in the overall building costs would have been a serious obstacle. The items above, however, can be included in designs without a significant increase in the overall cost.

At the same time, before and after every workshop, we analysed the approaches and the techniques implemented in order to let peasants ask, interact, opine, debate, etc. In other words, we needed to make sure that the peasants did not feel intimidated, insecure, or discriminated against. We needed to guarantee that they would become increasingly involved in the process of designing. We noticed that grass-root strategies were crucial to enforce long-term behaviours.

Such strategies became successful in the long run when we surmounted the initial resistance of people to give us personal information about their daily lives. It was not a case of modesty. Most of the time, especially at the very beginning of the workshops, they were very silent, they just listened. Basically, they were afraid that we might be political agents, tax inspectors, or the like. However, the moment they starting talking about their personal experiences and the problems in their houses, they became more interested in how to improve the thermal performance of their houses.

At the same time, at the beginning of the first workshops, political authorities were apprehensive and took some time to become comfortable and start participating. We should mention that women participated the most. Although they were silent while their husbands asked the first questions during the workshops, they soon participated and made accurate comments about the designs. It was a clear signal that they performed almost all of their activities at home. The size of the kitchen and the storeroom was a common concern. Incidentally, it was also the most common critique of the urban designs provided by FONAVI.

During the workshops, we pointed out the idea that practically every design decision would affect the quality of their house and, obviously, impact the total energy consumption. The need to keep this simple principle in mind throughout the workshops was our task.

As we know, in First World countries, the principle of energy consumption faces the environmentally-friendly policies that seek to reduce the CO_2 emissions. Nevertheless, in Third World countries, we have to keep an eye on quality of life, for these people can hardly consume fuel or gas like a person in a First World country does.

Fossil fuels, especially butane, used basically to cook and heat water, are expensive and beyond the budgets of the peasants. As poor cannot spend money on fuel or gas during winter there is not only a permanent lack of thermal comfort for everyone at home, but also recurrent health problems, especially lung diseases in small children and old people. Not surprisingly, Junin is one of the five municipalities of Mendoza that hold the highest infant mortality rate – a shameful 20%.

Passive solar energy education in workshops

The workshop content was organized according to the following schedule.

- Climate in Mendoza: seasonal fluctuations in temperatures, rainfall, winds, mid-day solar altitude during summer and winter, etc.
- Bioclimatological designs: principles, worldwide examples, passive solar energy houses, heat gains, cooling, and applicability of these principles in rural houses in Junin.
- Local weather according to personal experiences: official weather records for the area, comparison of local weather with the rest of the province, and theoretical adjustments that a house needs to improve thermal performances.
- Orientation: Concentration on passive solar system designs.

Peasants were already aware of the possibilities of improving the energy efficiency of their houses without increasing the overall cost. They were aware that orientation was the crucial factor to consider once they got the plot. We proceeded to show them a few plans of urban neighbourhoods to evaluate if those houses were properly orientated. After the previous workshops, they knew that the best use of sun gains during winter would be possible if the houses were well-orientated, that is towards the North (in our hemisphere). In their own words, a good orientation not only reduces energy costs in heating, but also provides amenity value for children and older family members.

We also prepared the main components of a house on a scale of 1:20 and simulated the sun's angle in summer and winter. We invited peasants to move the pieces around and analyse the good and bad aspects of each final design.

Building form and internal planning

As part of our teaching, we made sure that peasants knew that the building form would be influenced by planning regulations from FONAVI and the municipality. Still, we wanted them to know that they could get the best if they became involved in the planning process.

We also demonstrated how internal distribution of volumes affected ventilation, heat loss, and potential solar gain. They already knew (or perceived) that energy considerations related to overall surface. At this point, they imagined how internal planning would affect the potential to receive solar gain and they could determine the usefulness of the gain throughout the house. At the same time, they kept in mind that air movement was extremely important to ensure cross-ventilation for cooling during the long and warm summer. Again, we made them aware that variations in internal planning could enhance energy performance at little or no extra cost at all.

At last, peasants designed very basic houses on pieces of paper that Jorge Mitchell then drew following the appropriate scale. All in all, the designs had an acceptable coherence. Most of them have established functional areas in the house according to day and night activities. As shown in Figure 2, a corridor was the backbone of all the designs. This corridor joins the main access to the building – the front door – to a second door (lateral or rear) that went to the laundry and kitchen. The designs had many common aspects related to rural activities, including:

- big kitchen with a storeroom,
- three bedrooms due to the size of the family,
- a living room,
- absence of a garage, and
- a big laundry, close to a second entrance to the house.

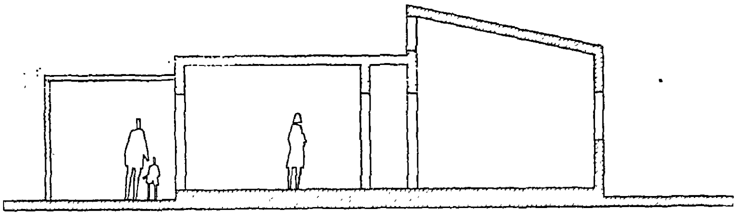


Figure 2 Sample design of a modified house

The kitchen was isolated from the rest of the house. Women wanted to keep this space for themselves to carry out their daily activities without the need to keep it neat and clean all-day long. The laundry would be used for personal cleaning after rural work. This room was connected to the bathroom where they could complete the appropriate personal cleaning before getting into the rest of the house. Rural workers would leave their dirty clothes in this laundry.

Peasants preferred the rectangular shape for future developments and for direct sun gains in most of the rooms. In the case of bedrooms, solar gain would be possible through windows located at the top of the wall. At the same time, roofs would be at an upper level.

Peasants placed the windows properly so they could allow direct solar gain in winter and cross-ventilation and cooling during summer. Windows towards the north were bigger to reduce heat losses during winter. They preferred vegetation for shade during summer months in those windows towards the North. A *parral* (a type of vine grown as a climber) was the common option because a *parral* in an open corridor would provide dense foliage during summer, but would lose all its leaves in the fall.

We should notice that vegetation has been the traditional option in our region among peasants who were descendants of Spaniards. We have to point out that a corridor with a *parral* allows many family activities to be performed outside during temperate days. Even in our balmy winter, this corridor is a social space for children to play and for the family to take lunch under the sun. Then, the open corridor should be considered a space with useful meanings that has to be integrated to the rest of the house. Other solar control devices like shadows and curtains were suggested.

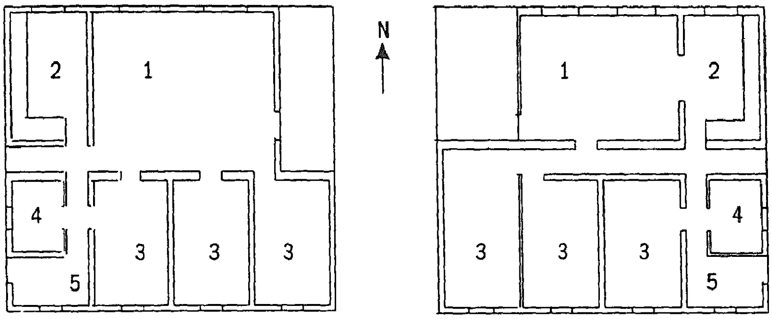
The last consideration deals with seismic engineering because it is compulsive in the region. FONAVI regulations are extremely clear in this respect and adobe houses are strictly prohibited. Fortunately, however, structures of reinforced concrete and thick brick walls (0.20 cm) have both acceptable thermal performances.

Peasants have some basic ideas about shapes and materials due to their daily experience. In most cases, peasants just ask for scientific explanations in order to confirm where to place a window in a room. Traditional adobe houses place a small- or medium-size window just in the middle of the wall. Peasants tend to keep this tradition along with the perception that a rectangular room and a rectangular house were the most appropriate ones. Typical layouts of the houses are shown in Figure 3.

From these designs, we were able to conclude that the transference of knowledge through the workshops was useful and that our objectives were successfully achieved.

Conclusions

In Argentina, low-income families have to build their houses under FONAVI regulations but available data demonstrate that these houses are not energy efficient, which is not a



† North; 1 - Living room; 2 - Kitchen; 3 - Bedroom; 4 - Bathroom; 5 - Laundry

Figure 3 Typical layout designs of the peasants' houses

minor detail considering that poor cannot afford to improve the thermal comfort by consuming fuel or gas. At the same time, the FONAVI budget is far from being enough to fulfil the increasing demand for social housing. According to our estimate, only 20% of the much-needed social housing can be built with that budget. To cope with such a situation, some peasants in Junin organized the NGO Calle Caballero to pool in both efforts and savings. For their part, the authors worked into a project of teaching peasants about passive solar energy designs.

During the workshops carried out in late evenings, during the fall of 1998, we demonstrated the value of taking into account the local weather, the orientation, site layout, solar control devices, and ventilation. We encouraged peasants to figure out how internal planning would affect the potential to receive solar gain. They considered the distribution of solar gain throughout the house and they kept in mind that air movement was extremely important to ensure cross-ventilation for cooling.

Their designs have in common a big kitchen with a storeroom, three bedrooms, a living room, and a laundry located close to the entrance because it would be used for personal cleaning after rural work. Among other things, peasants opted for a rectangular shape because it would allow for future developments and direct sun gains in most of the rooms. They placed windows to receive direct solar gain and for cross-ventilation and cooling. Also, vegetation was the most popular option for shade. As we all know, vegetation has other additional advantages in terms of quality of life. It adds value to a property in an arid region like Mendoza, protects a house from nasty winds and sharp solar radiation, and helps to create a well-appreciated micro-weather around the property.

Overall, peasants made good use of the knowledge about bioclimatological construction. Coherence and practicability in the designs demonstrated that workshops were the appropriate media for transferring scientific knowledge. Workshops proved to be effective because peasants became active after a short while. The fact that they could talk about their needs and propose their designs resulted in better designs. Once the paperwork is ready by the end of this year, Calle Caballero will receive the FONAVI loan and start building more appropriate houses. Workshops in Junin have been a pioneering experience in the province and will certainly guide other municipalities and NGOs. Last but not least, for the authors, the experience of helping people to improve their quality of life was priceless.

Acknowledgements
We would like to thank the municipality of Junin, CONICET, and the University of Mendoza for their assistance at different moments during the organization of the workshops. We also feel indebted to the peasants who attended the workshops. In many ways, although they may never imagine, they gave us the chance to experience that scientific knowledge can (and should) help poor people to enjoy a better life.

Session III

Miscellaneous topics

■

Physics with energy studies specialization: an experience
S K Samdarshi

■

Use of the Internet in renewable energy education
Joachim Göttsche

■

Training and education activities on solar buildings in India
Bibek Bandyopadhyay

■

Curriculum of a B. E. Civil Engineering course on renewable energy
Dulal Goldar

■

Human resource development for solar energy
Herbert A Wade

■

Role of renewable energy education in the development of arid regions
N M Nahar

Miscellaneous topics: summary

Renewable energy education: current scenario and future projections
pp. 167-168

Chairpersons

- Dr E V R Sastry
  Ministry of Non-conventional Energy Sources,
  Government of India
- Prof. M A R Akhanda
  Bangladesh University of Engineering and Technology,
  Dhaka, Bangladesh

Rapporteurs

- Mr Pradeep Dadhich
  TERI, New Delhi, India
- Dr G Datta
  Delhi University, New Delhi, India

The first presentation was by Mr S K Samdarshi from North Maharashtra University, who discussed his experiences with the new M. Sc. course on Energy Studies introduced recently at the University at Jalgaon. He informed that the response to this course was positive; 40% of the successful students were placed in graduate teaching, 20% in the energy industry, and some were absorbed by the computer industry. Female students are also actively participating in the course. There are some problems like the lack of proper library facilities and the high cost of reading material. Another observation was that the graduating students did not fare well in the GATE (Graduate Aptitude Test in Engineering) and the NET (National Eligibility Test), probably because they were asked more questions on pure physics rather than on energy. The delegates suggested greater emphasis on physics to remedy this.

The second speaker was Dr Joachim Göettsche from the University of Zimbabwe. He gave an interesting presentation on novel cooperation for postgraduate courses between institutes in Oldenburg and Harare. The faculty and students of the two universities are cooperating with the aid of latest methods like the Internet. There is also an active exchange of staff and students. A few scholarships have enabled some students to go to Germany to complete their research or thesis work. The shift from classroom lectures to learning from computers with emphasis on discussions has been greatly appreciated. It gives the students more time to do their own work in their own way.

Dr Bibek Bandyopadhyay from Ministry of Non-conventional Energy Sources highlighted the ministry's role in organizing one-, two- or three-day workshops and orientation courses, particularly in the field of solar passive buildings in India. He said that such workshops and seminars are being organized throughout the country to create awareness, generate public interest, and provide inputs about the technology to engineers, academicians, architects, and builders.

Dr Dulal Goldar of the Delhi College of Engineering presented a new curriculum of B. E. (Civil) in which various topics of RE (renewable energy) would be integrated in the existing subjects of the course. Students would also be able to choose from the RE topics as elective subjects. His presentation generated a lively debate whether this would be feasible for existing teachers with their knowledge of RE, in other words, the teachers should be trained first! Dr Goldar said that the teachers was adequately knowledgeable, but some audience members suggested that new teachers might be required to teach such courses, or teachers themselves would have to go in for refresher courses.

Ms Lalitha Balakrishnan, from the All India Women's Conference, presented the last paper of the session. She discussed operational strategies of informal organization and sustainable energy, and the role played by the word 'web site' in these exchanges. She also spoke of the various activities of the All India Women's Conference and the pollution problems faced by women who work with indoor *chulhas* (cookstoves).

School of Physical Sciences
North Maharashtra University
Post Box No. 80
Jalgaon - 425 001
India

S K Samdarshi

Physics with energy studies specialization: an experience

Renewable energy education: current scenario and future projections
pp. 169-181

Abstract

Energy studies as a specialization is being offered to M. Sc. (Physics) students by the Department of Physics, School of Physical Sciences, North Maharashtra University, Jalgaon, India, since 1992. Every year, 15 students of B. Sc. (Physics) are offered this specialization on the basis of their performance and their choice. From the very beginning, energy studies has been a popular choice. In the present study, a sample group of 50 students with M. Sc. degree with energy studies specialization has been taken and analysed vis-à-vis the response of students to the present course, the problems faced by them, their performance, expectations from the course, problems with regard to further studies and placement, and feedback from a few students pursuing activities related to energy studies.

Introduction

The NMU (North Maharashtra University), Jalgaon, was established in 1990. All the areas falling under its jurisdiction were earlier part of the Poona University, Pune. The NMU started its academic activities in 1991 and the Department of Physics is one of the six departments offering postgraduate courses in various scientific disciplines since then. Initially the Department of Physics offered specialization only in electronics. Later on, following the guidelines of the University Grants Commission, the NMU took the initiative and started offering interdisciplinary postgraduate courses in ES (energy studies) from 1992. Presently, it is being offered as specialization to the students of M. Sc. (Physics).[1] Every year, 15 students of B. Sc.. Physics/Electronics are offered this specialization on the basis of their performance and their choice. From the very beginning, ES has been a popular choice of students (Figure 1). The NMU follows the semester pattern and hence the curriculum for the ES students has been planned accordingly. In the present study, a sample of about 50 students of M. Sc. with Energy Studies specialization has been taken and analysed vis-à-vis the response of students to the present course, the problems faced by them, the performance of the students, their expectation from the courses, problems with regard to further studies and placement, and feedback from a few students pursuing activities related to energy studies. The data has been represented graphically and analysis of the results has been done.

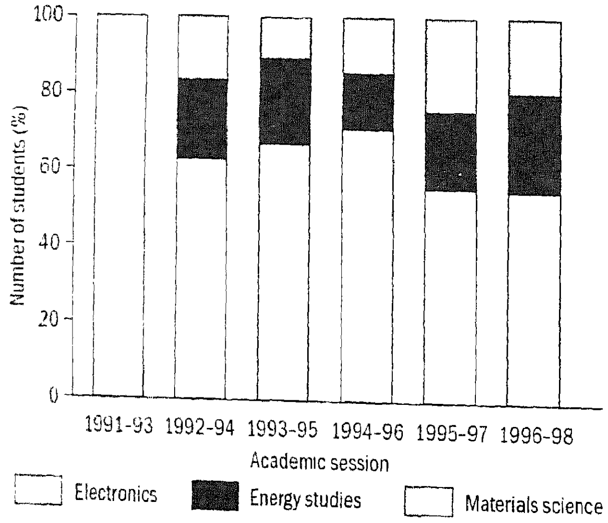


Figure 1 Students of different specializations in the school of Physical Sciences

---

[1] The UDCT (University Department of Chemical Technology) at the NMU offers an elective 'Energy resources and utilization' to the third-year B. Tech. (Chemical Engineering) and B. Tech. (Chemical Technology) students.

Course structure

Like other similar courses, M. Sc. (ES) has a curriculum divided into four semesters. In the first two semesters, students have to take compulsory papers of basic physics (Annexure 1). In the third semester, they are offered three specialized papers on energy. Of these, one theory paper is of a general nature intended to introduce the students to the conventional energy sources being used the world over, including India. A brief background for non-conventional sources of energy is also given. The other papers are Special Laboratory-I and project (this forms part of a two-semester project). The experiments and projects offered stress on various aspects of conventional and non-conventional renewable sources of energy. The fourth semester is fully dedicated to special papers on energy. Out of the three theory papers, two are related to various kinds of non-conventional energy sources. The third paper is on energy conservation and management methodologies and processes. Annexure 2 gives a brief account of the contents of the specialized papers on energy.

Student response

It is a fact that there has been a decrease in the number of students opting for M. Sc. courses in all Indian universities including the NMU. However, compared to other such courses, the response to M. Sc. (Physics) with an ES specialization has remained steady (Figure 1) at the NMU. Figure 1 shows the comparative picture of the popularity of the ES specialization along with the Materials Science and Electronics courses offered by the School of Physical Sciences.[2] It should be noted that only 25% of the total seats are offered to ES specialization.

Their sincerity and interest in the course is evident from their performance (Figure 2). This is despite the fact that they have to compete with students of other courses. The quality of students opting for ES also remained satisfactory (Figure 3) compared to other such courses. The ES course has attracted better students compared to the other two courses (specializations in common as well as compulsory courses). Figure 4 shows the popularity of the courses on the basis of sex.

---

[2] The Department of Physics has been restructured and is now called School of Physical Sciences with two departments, namely the Department of Physics and the Department of Electronics. The Department of Physics offers two specializations, energy studies and materials science, to M. Sc. (Physics) students.

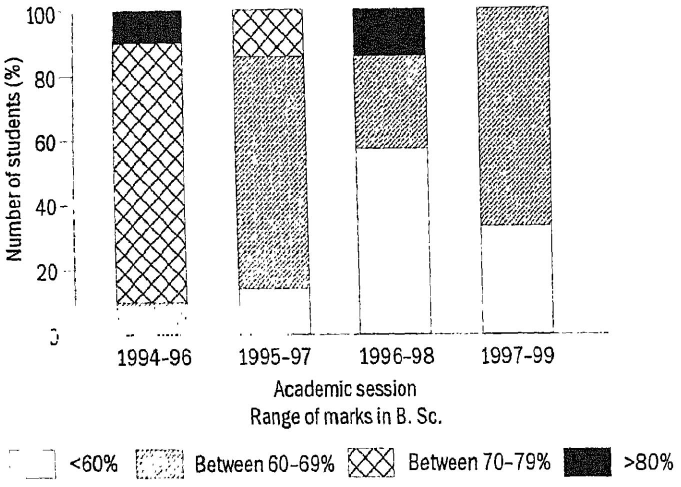


Figure 2 Distribution of students of different specializations on the basis of range of marks during M. Sc.

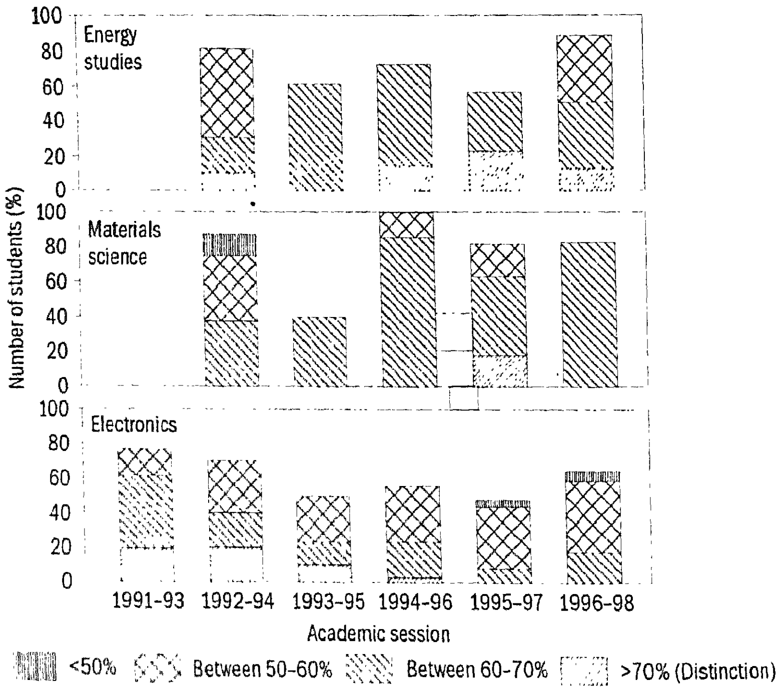


Figure 3 Distribution of students opting for M. Sc. (ES) on the basis of range of marks at B. Sc. level

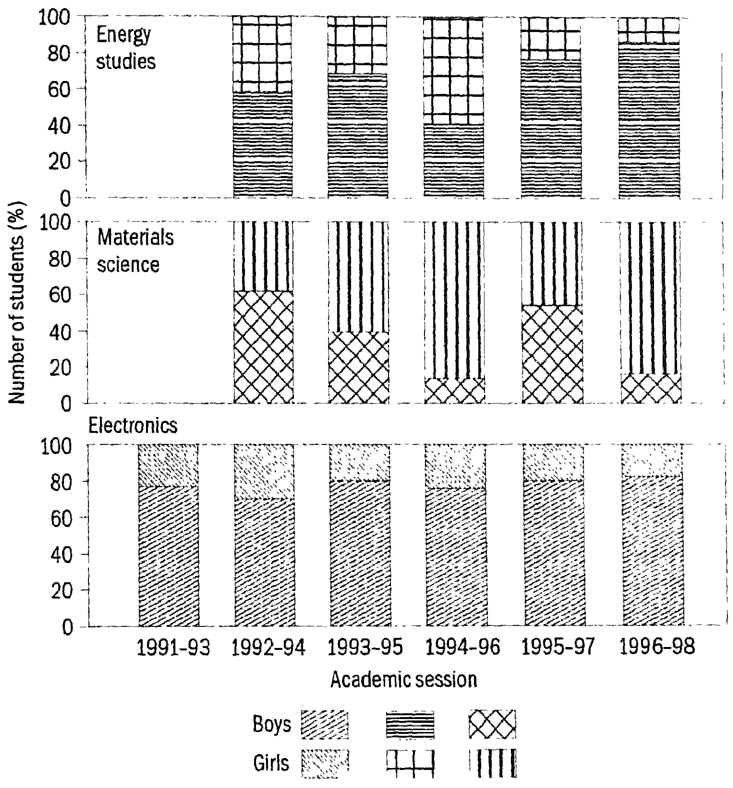


Figure 4 Distribution of students of different specializations on the basis of sex

Problems faced in the energy studies course

Both students and teachers face numerous problems. Any course needs standard textbooks which are easily available and affordable. There are not many standard books available in India at affordable prices which cover all aspects of energy and the related courses. A few books (Garg 1982; Sukhatme 1984; Garg and Prakash 1997) on the thermal conversion of solar energy are available. Some excellent reviews (Sodha et al. 1984; Garg, Mullick and Bhargava 1985) and data books (Mani and Rangarajan 1982) are also available. Organizations/institutions like the Tata Energy Research Institute, New Delhi, and the Ministry of Non-conventional Energy Sources, Government of India, have published a few handbooks, monographs, and books on energy economics and energy policy issues. But there is a complete lack of standard textbooks covering various new and renewable sources of energy. Standard textbooks on energy conservation and management aspects are also not available. Proper documentation for energy-related experiments for M. Sc. students is either not fully developed or needs a lot of effort and investment because of the unavailability of tailor-made systems. Basic measuring instruments such as pyranometers, pyrheliometers, emissonmeters, and sunshine duration recorders are also not supplied at competitive prices. It is possible to develop many experiments with a little creative effort and minimal investment, but this is limited to the solar thermal area. A concerted effort is needed from energy experts to develop a curriculum for experiments related to energy not only for postgraduate but undergraduate levels as well.

A project for the preparation of teaching/learning packages for undergraduate and postgraduate levels in the area of renewable energy engineering is being supported by UNESCO (United Nations Educational, Scientific, and Cultural Organization), New Delhi. The UNESCO Chair project in Energy Engineering at the Centre for Energy Studies, IIT (Indian Institute of Technology), New Delhi, has also done commendable work by bringing out such material (Garg and Prakash 1997). However, it is required to involve many more universities in this abovesaid project. Very few institutions in the country offer refresher courses in interdisciplinary areas like ES. This is a problem with other interdisciplinary courses as well. There is an urgent need to organize such courses to save a teacher's knowledge from drying up. University teachers engaged in research activities are informed about developments in the area, but the teachers of engineering faculties in various engineering colleges which offer energy courses face this problem.

Student performance

The performance of the NMU students in the M. Sc. courses offered by School of Physical Sciences can be judged from the distribution of the marks secured by them (Figure 3). As the marks are based on internal and external assesments with 40% and 60% weightage respectively, the probability of overstatement in their respective performance record is minimized. The M. Sc. (ES) students in particular have performed very well. This is apparent from the fact that in all the five batches of M. Sc. (ES/materials science/electronics), an ES student has invariably topped the list. This also shows that ES has attracted the best available students. The projects done by them have been based on various theoretical and experimental aspects of photothermal, PV (photovoltaic), and other renewable sources of energy. The topics were related to growth and characterization of thin films for PV applications, solar ponds, transparent insulating devices, solar cookers, study of the calorific value of fuels, and the performance of improved cookstoves, solar stills, etc. Some project work done by these students has been published in international journals.

Course expectations

Expectations of the students and those of the various types of employers are different. After finishing this course, students endeavour to go on for either higher studies or for a job. The options for higher studies are limited: either an M. Tech. degree or research leading to a Ph. D. As far as an M. Tech. in ES is concerned, it is offered only by IIT Delhi, IIT Mumbai, and IIT Kharagpur. An M. Tech. degree in Energy Management is offered by the Devi Ahilya Vishwavidyalaya, Indore. The Madurai Kamraj University also offers an M. Phil. degree after M. Sc. (Jaiprakash and Kumar 1994). All these courses are open to M. Sc. and BTech degree holders of various disciplines. The students of M. Sc. (ES) can do a Ph. D. in energy studies at the NMU; the Guru Nanak Dev University, Amritsar; the Sardar Patel University, Vallabh Vidyanagar (Gujarat); and the IITs mentioned above. The Institute of Technology, Banaras Hindu University, Varanasi also offers a Ph. D. in energy areas. A more comprehensive list of institutions offering energy and related courses is given in Annexure 3.

A organization whether involved in R&D or manufacturing, has two expectations from future employees. It wants the employee to be highly trained in both the theoretical and experimental aspects so as to understand every detail of various energy devices. The person should be good at the mechanical, chemical, electrical, and electronics engineering aspects also. A basic background of mechanical, chemical, electrical, and electronics engineering is an essential part of device manufacturing. The knowledge of techno-economic aspects is equally desirable. The students of M. Sc. (ES) are suited well for all these but they lack knowledge of engineering aspects. This hinders their growth in energy industries. There is no doubt that they are best suited for R&D activities because of their versatility.

Higher studies and placement

The M. Sc. (ES) students wanting entry to M. Tech. (ES) courses are required to take the GATE (Graduate Aptitude Test in Engineering) examination. They have to compete with students of other specializations of physics. Also, they are not given preference over students of M. Sc./B. Tech. with other specializations for admission to M. Tech. courses at the IITs. Their GATE scores are obviously less because there is not even a single question related specifically to the papers which they do as their specials during their M. Sc. Students from other specializations do not face this problem. It is essential, therefore, to have energy as a paper in the GATE examination.

A limited number of students pursue research also, but they too face similar problems. The NET (National Eligibility Test) is organized jointly by the UGC (University Grants Commission) and the CSIR (Council for Scientific and Industrial Research) for admission to various Ph. D. courses and to be eligible for lecturership. In this case, the problem is in the structure of the syllabus of the NET examination. It favours students with electronics/materials science/solid state physics/nuclear physics specializations. It has been seen that even in the NET or state-level eligibility tests for lecturership, many questions of a highly specialized nature are posed in the physics paper. This affects the job prospects of students interested in teaching because very few of them qualify. The only solution to this problem is to have energy specialists as paper setters for these tests.

As the NMU being a new university, its basic infrastructural facilities are still being developed. Jalgaon and Dhule districts, which form the catchment area of this university, have the largest tribal population in Maharashtra. In spite of this, a few students have taken the initiative to join the courses and are presently working for national-level institutions. It is desirable for the persons involved in energy research to work out a plan to have regular expert lectures on energy in such institutions on a collective basis. This is more important for the institutions located in such rural areas because renewable energy has more meaningful applications in such areas.

As far as job prospects in research are concerned, M. Sc. (ES) holders have limited openings and scope unless they already have some higher degree(s). New energy industries offer a few openings to M. Sc. (ES) students in marketing and quality control. But lack of training in the engineering aspects of energy production and conservation devices is a major obstacle. They cannot be absorbed into production-related work. This creates problems as far as job satisfaction and professional growth is concerned. Figure 5 shows the present status of students who have graduated from the NMU. Most of them have opted for jobs which are not connected at all with energy-related activities. From the available data it has been seen that only about 20% of them are engaged either in R&D or in industries related to energy. A minority are teaching Physics (16%) and computer-related activities (3%). About 23% are still pursuing further studies. The rest have

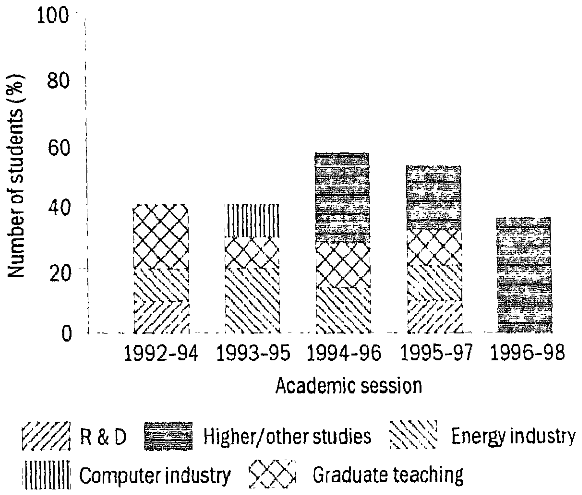


Figure 5 Status of M. Sc.(ES) students just after completion of the degree

taken up completely different professions. Only 70% of the students admitted to ES have passed till now and 62% of these are either working or pursuing further studies. On the basis of the percentage of students admitted to the course, 43% are engaged in various activities and 14% are engaged in activities related to energy. An effort is needed to make this scenario better.

Conclusion

The courses with specialization in energy studies have certain common and certain specific problems. Hence, blanket remedies cannot be provided. However, the problems can certainly be identified and need to be rectified through discussions on a common platform, followed by concrete proposals and collective action.

1. A general problem is the lack of teaching/learning material. The efforts being made by individuals, organizations, and institutions in this regard have met with only limited success.
2. Problems with regard to higher studies for M. Sc. (ES) students, specially aspirants of an M.Tech. degree, need to be sorted out at the earliest. This calls for efforts to bring to the notice of authorities responsible for conducting the GATE examination that a paper on energy must be included. Also, preference should be given to the M. Sc. (ES) students for taking up M.Tech. (ES) and PhD courses.

3. A two-pronged effort must be adopted to solve the problem of the placement of M. Sc. students. The course content needs to be reoriented and basic engineering papers introduced into the M. Sc. curriculum. There is also a need to offer special papers to the students of ES so that they become specialists in different renewable areas. On the other hand, the demand of highly-trained manpower in industries and institutions needs to be monitored. This is because any kind of lopsided development can lead to wrong directions.
4. More meetings of energy specialists must be conducted with the sole purpose of giving proper directions to courses on energy.
5. There is a need to organize lectures by energy specialists in various institutions at regular intervals.
6. Special attention must be paid to new universities so that they are given a better direction to fulfill future needs and aspirations.

References

Garg H P. 1982
Treatise on Solar Energy
England: John Wiley & Sons.

Garg H P, Mullick SC, and Bhargava A K. 1985
Solar Thermal Energy Storage
Holland: D Reidel Publishing Company.

Garg H P and Prakash J. 1997
Solar Energy Fundamentals and Applications
New Delhi: Tata McGraw Hill Publishing Company Ltd.

Prakash J and Kumar N. 1994
Energy Studies as a part of Physics Curricula
Physics Education (July–September 1994) p. 165.

Mani A and Rangarajan S. 1982
Solar Radiation Over India
New Delhi: Allied Publishers.

Sodha M S, Mathur S S, and Malik M A S. 1984
Reviews of Renewable Energy Resources, Vol. 2
New Delhi: Wiley Eastern Ltd.

Sukhatme S P. 1984
Solar Energy
New Delhi: Tata McGraw Hill Publishing Co. Ltd.

Acknowledgements

The author acknowledges the All India Council for Technical Education for providing the facilities for analysis. The help extended by Dr V C Kolhe, Director, Board for University and College Development, and Mr S D Deshmukh, Examination Controller, the NMU, Jalgaon, is gratefully acknowledged.

Annexure 1

Courses offered to M. Sc. (ES) students in each semester

1. Semester I
    - ES 101 Mathematical methods in physical sciences
    - ES 102 Classical mechanics
    - ES 103 Quantum mechanics
    - ES 104 Electronics
    - ES 105 General laboratory–I

2. Semester II
    - ES 201 Solid state physics
    - ES 202 Statistical mechanics
    - ES 203 Electrodynamics
    - ES 204 Computational methods and computer programming
    - ES 205 General laboratory–II

3. Semester III
    - ES 301 Physics of semiconductor devices
    - ES 302 Atomic and molecular physics
    - ES 303 Global and Indian energy scenario
    - ES 304 Special laboratory–I
    - ES 305 Project

4. Semester IV
    - ES 401 Solar energy conversion–I
    - ES 402 Solar energy conversion–II
    - ES 403 Energy conservation and management
    - ES 404 Special laboratory–II
    - ES 405 Project

Annexure 2 Contents of the specialized courses on energy

- ES 303 *Global and Indian energy scenario*
  Importance of energy in the modern industrial society; energy utilization and demand pattern in the different countries; commercial and non-commercial energy resources; fossil fuels: coal, oil, natural gas, nuclear energy (resources, demand, and techniques for conversion); energy crisis; thermonuclear energy; hydropower and its potential; Indian energy scene; alternative energy resources for future; energy and environmental pollution; and energy policy issues.
- ES 401 *Solar energy conversion–I*
  Importance of solar energy; sun; nature of solar radiation; measurement of solar radiation; solar thermal devices; flat-plate collectors, energy balance equations, heat loss evaluation, and efficiency determination; selective coating types, materials, and techniques; concentrating collectors and their types, principle of working, and applications; thermal energy storage; and design aspects of solar thermal systems.
- ES 402: *Solar energy conversion–II*
  PV devices; solar cell technology; other materials for solar cells; PV systems; storage batteries for PV systems; wind energy; bioenergy; bio-conversion; and hydrogen energy.
- ES 403: *Energy conservation and management*
  General principles of energy management; planning for energy management; management of heating and cooling; electrical load and lighting management; energy audit and energy efficiency analysis; economics of energy efficient usage; energy conservation in boilers, process heating, burners, furnaces, and electrical and mechanical devices; waste heat recovery techniques; and energy saving through use of alternative energy resources.

Annexure 3

List of institutions offering M. Tech./PhD courses in energy

Name of the institution	Courses	Specialization/department/centre
IIT, Chennai	M. Tech./Ph. D.	Energy Systems Engineering Electrical Engineering
IIT, Delhi	M. Tech./Ph. D.	Centre for Energy Studies
IIT, Mumbai	M. Tech./Ph. D.	Department of Energy System Engineering
IISc, Bangalore	M. Tech./Ph. D.	Thermal Science and Energy Systems (Mechanical Engineering)
Institute of Postgraduate Studies and Research, JNT University, Hyderabad	M. Tech./Ph. D.	Energy Systems (School of Energy)
Sardar Patel University, Vidyanagar, Vallabh Vidyanagar, Gujarat	Ph. D.	Energy Department of Physics
B V Boomdreddi College of Engineering and Technology	M. Tech./Ph. D.	Energy Systems Engineering (Mechanical Engineering)
Devi Ahilya Vishwavidyalaya Indore	M. Tech./Ph. D.	Energy Management (Department of Energy Science)
Pondicherry Engineering College, Pondicherry	M. Tech./Ph. D.	Energy Technology (Mechanical Engineering)
Arulmigu Kalasalimgam College of Engineering, Krishnakoil (Tamil Nadu)	M. Tech.	Energy Engineering (Mechanical Engineering)
College of Engineering, Anna University, Chennai	M. Tech.	Energy Engineering (Mechanical Engineering)
Bharatidasan University	M. Tech./Ph. D.	Energy Conservation and Management (School of Energy)
Institute of Technology, Banaras Hindu University, Varanasi	M. Tech./Ph. D.	Energy Engineering (Chemical Engineering)
Faculty of Science and Technology, Jadavpur University, Calcutta	M. Tech./Ph. D.	Energy Science and Technology (School of Energy Studies)

Renewable Energy
Programme,
University of
Zimbabwe,
PO Box MP 167
Harare
Zimbabwe

Joachim Göttsche*, J Schumacher, D J Simbi

Use of the Internet in renewable energy education

Renewable energy education: current scenario and future projections
pp. 182-189

Abstract

This paper discusses the cooperation programme in REE (renewable energy education) between the Carl von Ossietzky University of Oldenburg and the University of Zimbabwe. Intensive use of electronic mail for communication is considered critical to the success of the programme. The choice of the electronic medium of communication is important with respect to the execution of the administrative activities of the cooperation programme. The possibility of developing common courses and interactive teaching modules by the two universities involved via the Internet is seen as a starting point in the formation of international links between institutions involved in RE from an industrial application, research, or educational perspective. Further developments are envisaged in the use of e-mail to facilitate collaborative research and project supervision. The option of extending the use of the Internet to post-graduate training in RE by distance education is also discussed and the limitations noted.

---

* Author for correspondence

Introduction

Recently, the Faculty of Engineering at the UZ (University of Zimbabwe) entered into a cooperative agreement to offer postgraduate study programmes in REE with the assistance of the OU (Carl von Ossietzky University of Oldenburg). The driving force for this activity in Zimbabwe is the need to become self-reliant in energy resources other than those based on fossil and nuclear power generation. The project, supported by the GTZ (German Agency for Technical Cooperation), aims to establish an REE base for the country and perhaps the Southern Africa region. At the onset, attention has been focussed on developing the human resource base so as to ensure sustainability of the programme in RE at the UZ. In order to achieve this objective, two major activity areas have been identified as requiring urgent attention: human resources development, and teaching and research. These are sub-divided into a number of elements.

- Human resource development
  - Staff development for UZ up to Ph. D level
  - Staff exchange between OU and UZ
  - Research and industrial attachment for UZ students in Germany
  - Processing of scholarships for UZ students

- Teaching and research
  - Development of common course units
  - Development of shared databases
  - Development of shared lecture notes
  - Collaboration in research activities

It is apparent that there should be intensive communication between OU and UZ for any of the activities outlined above to be achieved successfully. The traditional modes of communication i.e. telephones and transport have tended to be expensive and fraught with delays. In recent years, e-mail, particularly the Internet, has become the choice mode of information transmission and retrieval.

This paper further discusses the teaching and research aspects of the cooperation programme that can be developed into activities for the Internet.

Internet options for international cooperation

For any international cooperation activity to be successful, there has to be shared vision, open dialogue, and intensive communication. Traditionally, communication in cooperation activities has relied essentially on telephone, facsimile, and regular mail. In situations where it has been impossible to successfully communicate using any of the above modes of communication, costly travels have been undertaken to facilitate dialogue. This has been the experience in many international cooperation activities between industrialized and developing countries. This affects the decision-making process. In this respect, poor communication will not only affect decision making but also the conclusion of agreements and the implementation thereof.

The rapid expansion in communication and transport in the last decade is not only making global economy a reality, but is also facilitating the removal of barriers inherent in traditional economic, social, and educational structures. In this regard, trends towards globalization should be seen as fast transforming communication. The progress in information technology seems to be the driving force behind this globalization. The Internet, with its e-mail facility, is proving to be an effective yet inexpensive communication tool for the informal transmission of information. In addition, it is providing a quick means for exchanging documents and experimental data between researchers in different parts of the world. The main advantage in the use of the Internet is the immediate and world-wide availability of information, which can not only be read on the screen but can also be downloaded and subsequently printed to become part of mutually-shared teaching materials.

E-mail facility is now available at most universities in developing countries including the University of Zimbabwe. However, access to the Internet is often not easy as presently is the case at UZ where the facility is very centralized with only a few terminals available for the whole university. The situation is, however, likely to change before the new millennium.

To date, use of the Internet to communicate by international university communities has been mainly between individuals. The option of addressing larger audiences as part of the teaching activity is still in its early stages (Rowley 1997). There are, however, a few institutions, including UZ, who are participating in trial programmes, the African Virtual University being an example. This is a large undertaking that is already making use of the limited resources of the internet facility at UZ (Baranshamaje 1995). The programme envisages the setting up of a whole 'university without walls' for sub-Saharan Africa.

Renewable energy education via the Internet

The discipline of RE is still in its infancy. There is, therefore, a very strong need for individuals working in the RE area to form close ties/contacts with persons or groups doing similar work (teaching or carrying out research in RE) in other parts of the world. Rapid information exchange across the world is now technically possible through the Internet. The RE sector (industry, research, and education) is still relatively small and should take advantage of the effects of a globalized economy and the information revolution to develop and build its database. Currently, nowhere in the world is there a critical mass in either industry, research, or education at any one location that would allow the development of strong independent RE systems.

An engineer who is fairly active in the field of RE should be able to obtain information as well as make contacts on a worldwide scale. This, however, requires training and practice in order to make maximum use of the Internet facility and the options on offer. In this context, tertiary education centres operating in the field of RE must play the crucial role of introducing the use of the Internet in their teaching activities. A network of institutions that allows the sharing of teaching materials and eventually the offering of common course units should be created. The cooperation in the teaching of RE between OU and UZ should thus be seen as a first step in the creation of such international institutions.

It has been pointed out that developments in education and training stress the need to utilize modern technology efficiently. 'This includes multimedia computer-assisted learning (CAL) packages which are often in CD-ROM format. These offer the potential to include still images and sound and video recordings as an integral part of an interactive package. Another important recent development has been the conception of the Internet and the WWW (World Wide Web). This has vastly expanded the facility of information retrieval and dissemination, and has huge potential in the field of education, especially when combined with other electronic communication technology.' Some of the opportunities offered by the Internet and the WWW include:

- global access to courses and relevant information,
- means to locate and access relevant information efficiently,
- access to a large, expandable resource base (including software) covering a broad range of material,
- means to facilitate a flexible approach to learning, including group, distance, and collaborative learning,
- ability to update course material easily,
- storage, manipulation, and presentation of information by using a range of formats (e.g., text, spreadsheets, graphics, video, and sound),
- frameworks to enable learners to work independently through tutorials, dialogues, and problem solving exercises,

- courses may be accessed at the users' home or place of work,
- employee training may be with no significant extra cost (e.g., less travelling costs and less loss of working time),
- assisted and guided learning by means of maps, pathways, navigation tools, and browsing tools,
- easy downloading of paper-based teaching resources, and
- interaction using various conferencing and task work applications software.

There is, however, the need when utilizing the WWW, to develop distance learning programmes to ensure that courses are researched, planned, and developed according to the advantages and limitations of the new technology.

Development of Internet activities to facilitate bilateral cooperation

Within the framework of the bilateral cooperation between OU and UZ to facilitate the provision of postgraduate education in RE at UZ, the planned activities fall into two categories: human resources development (administrative) and teaching and research (education). With respect to the first category, use of e-mail is necessary to facilitate the communication of the decisions made either at OU or UZ. Here the e-mail facility is being used as an administrative tool for the programme. The second category which addresses the educational matters has to be discussed in more detail following the sub-headings proposed earlier and will include further developments of the postgraduate courses in RE into distance education activities on the Internet.

Development of common courses

A common Internet course will be based on a mutually agreed syllabus, which will, at the same time, provide the structure of a tree of web pages that become more explicit level by level. The pages will provide reading material, literature references, questions, problems with model solutions, assignments, instructions for practicals, access to software tools, and addresses of related web sites of research groups, companies, etc., where applicable.

However, a complete educational web site may still not be able to replace direct contact between lecturers and students. In an early stage, the WWW information may just be seen as a new form of lecture notes provided to students attending lectures in a normal way. In an advanced stage, student-lecturer contacts will be reduced to discussion sessions, students' presentations, tutorials, and practicals. At this stage, the online teaching material will be a multimedia product and will contain, for example, sound and video recordings as an integral part.

It should be noted, however, that without guidance, the overwhelming information offered may not be used efficiently by the student, as he/she will probably have no previous experience with the Internet tool. It is necessary, therefore, that the options and shortcomings of the Internet be explained and discussed thoroughly before letting the student 'play' with the fashionable tool.

Development of interactive teaching modules

The term 'interactive' in the context of teaching modules has often been used without the existence of real interaction. In this context, the term 'interactive' means that in the course of his/her study, the student may not only go through the material as discussed in the previous section but will get a feedback from the system as well.

A simple example is the solution of problems, where the student has to type his answer, e.g., the required size of a PV generator for an energy system layout problem, and will immediately receive a response telling him whether his solution is correct or not. The access, e.g., to solar radiation databases or system simulation tools can be built into a web page so that the student can choose or search for specific information of interest.

Development of a common case study

The teaching module case study was introduced very early into the curriculums of the M. Sc. programmes in REE at OU and UZ. The case study, as an interdisciplinary unit, deals with project management issues as well as questions concerning system layout and project implementation. In the real world, many RE projects have failed not because of technological or economical reasons but because of improper assessment of the implementation procedure, with respect to the social and cultural environment in which the systems were intended to operate. Therefore, this course unit is an essential part of both curricula.

In the case study unit, students are requested to analyse a specific local situation and come up with recommendations regarding development and energy supply options. Thorough system layout and design has to be accompanied by suggestions of the steps to be taken for sustainable project implementation. Students are expected to work in teams.

In a common case study, there would be a local group and a distant group working together on the same case situation. Efficient cooperation and coordination e.g. between partners in industrialized and developing countries could be practised in this way. Resources available at both ends would contribute to the problem solution, and probably to a better result.

Collaborative research and supervision of student projects

The Internet makes it possible for a student to communicate his/her problems and results to the supervisor without having to physically meet him/her. This often happens when the supervisor and the student have been separated either because the student has travelled to do his industrial attachment or to conduct research abroad, or because the supervisor has travelled as a guest lecturer or a research fellow.

In any case, communication between the supervisor and student should not be interrupted for that period because the solution to problems might be delayed unnecessarily. Even in critical phases, e.g., when the deadline for reports is coming near, the exchange of draft versions and their corrections/ comments is made easy by using the option of sending documents as attachments with e-mail messages.

In case of collaborative research, write-ups of reports or discussion of research results should be possible using e-mail.

Further developments into distance education

With the materials for common courses being developed as described above, it is natural that the next step is to further develop the course units so that they may be used in the framework of a distance education programme. However, a complete M. Sc. course in RE offered through distance education would still require a substantial presence phase because of the required practical work with RE systems, which cannot be replaced by virtual reality.

Conclusion

The Internet together with the WWW offers overwhelming opportunities to international cooperation activities in REE. The option of networking is especially important for areas of teaching and research which are new and/or allow only relatively small staff numbers. The swift international linking of institutions operating in the field of REE allows extensive and global use of resources that would otherwise only be available to a small local environment.

The close cooperation between the postgraduate programmes in RE at the universities of OU and UZ as laid out in this paper is to be seen only as the starting point of a potential intensive network of postgraduate training centres around the world using the Internet.

References

Rowley P. 1997
Experience of a Global Course in Renewable Energy Delivered via the Internet and World Wide Web
Available at: http://www.eng.dmu.ac.uk/~rowley/pap4.html

Baranshamaje E. 1995
The African Virtual University (AVU): Concept Paper
Available at: http://207.196.68.148/avusite/about/index.cfm?location=concept

Rowley P, Twidell J, Batley S, Chadwick H. 1996
Strategy and Methods for Conducting Renewable Energy Education on the Internet
Paper presented at the International Symposium for Renewable Energy Education, 22-24 September 1996, Oldenburg, Germany

Ministry of Non-Conventional Energy Sources,
Government of India
Block No.14
CGO Complex
Lodhi Road
New Delhi - 110 003
India

Bibek Bandyopadhyay

Training and education activities on solar buildings in India

Renewable energy education: current scenario and future projections
pp. 190–198

Abstract

India is a vast tropical country and has a variety of local climates ranging from severely cold to extremely hot. As a result, shelter is a matter of concern from the point of view of energy and resource conservation. Buildings, in the given climatic conditions of the country, need a considerable amount of energy to provide lighting, heating, and cooling facilities. With the steady growth in urbanization and industrialization and with improvements in the standard of living, energy consumption in this sector is expected to increase manifold. It is, however, also an area where substantial savings of energy can be achieved. Passive solar architecture, which is a climate-responsive architectural design and art form, reduces the consumption of electricity or other fuels required to keep the interior of a building comfortable. Through a training and education programme undertaken by the Ministry of Non-Conventional Energy Sources, Government of India, under its Solar Buildings Programme, workshops and seminars are being organized every year throughout the country for creating awareness, generating public interest, and providing inputs about the technology to engineers, academicians, scientists, planners, builders, students, and potential house owners. This paper[1] makes a detailed presentation and analysis of the training and education programme being implemented during the last few years.

---

[1] The paper essentially presents the SBP (Solar Buildings Programme) of the Ministry and attempts an analysis of the same. However, the opinions expressed by the author in this paper are those of the author in his individual capacity and do not necessarily reflect the views of the ministry. The contributions made by the various officials of the ministry and the state nodal agencies, architects, engineers, and the faculties of various universities, colleges, institutes, and other organizations in developing this programme are gratefully acknowledged.

Introduction

India is a vast country with a land area of over 3.2 million km^2 and a population of nearly 950 million people. Its mainland area has between latitudes $8^0 4'$ and $37^0 6'$ North. It has a varied land form and a variety of local climates ranging from extremely hot to severely cold. Certain places enjoy a moderate climate throughout the year. This diversity has long been recognized. The climate in this country, as elsewhere in the world, has traditionally determined the form of shelters. Shelter is, by definition, a means to protect oneself from the extremes of nature. Nevertheless, apart from the local climate, shelter also reflects religion, culture, technology, and locally available building materials. In India, vernacular architecture is an appropriate example of such developments that use climate as a resource and provide more or less comfortable living conditions with minimum use of external energy.

Modern architecture, with its many significant achievements is, however, heavily dependent on commercial energy sources for providing lighting, heating, and cooling facilities in buildings. The energy requirement for keeping building interiors cooler in summer and warmer in winter and also for lighting is quite significant. In India, energy consumption in the building sector is progressively taking up a larger share of the total energy generated.

Passive solar architecture is a climate-responsive architectural design and art form, which can be utilized to minimize the impact of climate both in summer and in winter. It also includes daylighting strategy. Other solar technologies such as water heating and lighting represent promising energy supply alternatives for residential and non-residential buildings. These solar technologies can effectively convert either solar radiation into thermal energy to closely match the temperature requirements of a variety of end uses or can provide decentralized electricity of any magnitude from a few miliwatts to kilowatts or megawatts. Adoption of a solar-efficient building design concept, therefore, reduces electricity consumption or other fuels required to keep the interior of a building comfortable and productive.

The Solar Buildings Programme

As a result of R&D activities on solar building design concepts undertaken in the last two decades by the Department of Science and Technology and the MNES (Ministry of Non-Conventional Energy Sources), Government of India, the weather data of the country has been analysed (Mani and Rangarajan 1982), climatic classification has been made (Bansal and Minke 1988), a number of design concepts and design guidelines evolved, and a few buildings constructed

(Gupta 1992) to validate the theoretical models. Since 1994, through a comprehensive solar passive architecture programme, the MNES has undertaken several activities to promote the energy-efficient building design concept in the country. The programme has, of late, been renamed as the SBP (Solar Buildings Programme) (Bandhyopadhyay 1997a; Bandhyopadhyay 1997b; MNES 1984–98).

The primary objective of the programme is to promote energy-efficient building designs through the optimum use of available solar energy and other forms of ambient energy in building energy management. The specific activities being pursued under the programme are detailed below.

Research and development

These R&D projects are sponsored at universities, national laboratories, and other research institutions with the objective of developing suitable design techniques and concepts, software packages, architectural instruments, materials, thumb rules, etc., for solar-efficient buildings.

Training and education

Workshops and seminars are being organized throughout the country for creating awareness, generating public interest, and providing inputs about the technology to engineers, academicians, scientists, planners, builders, students, and potential house owners. Orientation courses are regularly being organized for architects to make them familiar with the new developments and to motivate them for adopting solar-efficient building design concepts. Activities are also being undertaken to develop suitable curriculums for students of architecture.

Awareness creation

The awareness programme envisages creating awareness about the technology through the publication of popular literature and also specialized books for architects and engineers, publicity through various media, etc.

Demonstration

To demonstrate the concept of solar buildings, the MNES accepts proposals for the design and construction of solar buildings from government and semi-government organizations. To encourage these organizations to construct their new buildings on the basis of solar design principles, the ministry provides partial financial assistance to the extent of 50% (up to a maximum of Rs 50 000) for the preparation of DPRs (detailed project reports) of such buildings and also 10% of the cost of construction (up to a maximum of Rs 1 000 000) of buildings in government and semi-government sector only.

Training and education

Training and education has been identified as a major activity to encourage the application of energy-efficient technologies and to increase their market penetration. This has also been recognized as a major policy intervention tool for initiating measures which would have far-reaching consequences in achieving the objective of energy efficiency and environment protection.

Since the inception of the programme, more than 50 such training programmes have been organized in different parts of the country. Every year, around 10 such programmes are targeted. The programmes include both one-day workshops or seminars and orientation courses of three to five days duration. They are normally being organized by research institutes, universities, colleges of architecture, engineering colleges, state nodal agencies, and other professional organizations. Necessary financial support for organizing these programmes/courses is provided by the ministry.

The details of the short duration programmes (workshops of one-day duration) are given in Tables 1 and 2. Some of

Table 1 Solar buildings workshop I

Duration	Content	Participants	Objective	Details
One day	General	Planners, administrators, engineers, builders, academicians, students, architects	Disseminate information; create awareness; educate decision-makers; motivate the target group to adopt these concepts	▪ Basic concepts of energy resources ▪ Energy-environment relationship ▪ Energy conservation and energy efficiency ▪ Solar-efficient buildings ▪ Renewable energy appliances for buildings ▪ Costs and benefits

Table 2 Solar buildings workshop II

Duration	Content	Participants	Objective	Details
One day	Special topics	Professionals including architects, researchers, engineers, consultants, academicians, etc.	Develop a group of professionals in this sector; crystalize the knowledge base in this area	▪ Energy-efficient lighting ▪ Daylighting ▪ Energy-efficient windows ▪ Building codes ▪ Building software

these programmes are general in nature (Workshop I) and some are focused (Workshop II). The objectives, the programme content, and the targeted participants have been elaborated in the tables. A few such typical programmes organized over the years in different cities of the country are listed in Table 3 and 4. While the programmes with general contents impart basic understanding, highlight benefits, and enthuse the general public, the more focused programmes help to educate a group of professionals and to crystalize the knowledge base in the area.

The orientation/refresher courses, which are normally of three to five days duration, are of special interest to the practising architects. Table 5 shows a few representative orientation/refresher courses organized at different times in different places of the country. The architects, by virtue of their training, are normally aware of these new concepts of energy

Table 3 Workshops/seminars (representative)

Workshop/seminar	Place and date(s)	Organizer(s)
Solar passive architecture	Calcutta 24 March 1994	West Bengal Renewable Energy Development Agency, Calcutta; Housing and Urban Development Corporation, New Delhi
Solar passive architecture	Thiruvananthapuram 5 August 1995	Agency for Non-conventional Energy and Rural Technology, Thiruvananthapuram
Solar passive architecture	Bhubaneshwar 21 December 1995	Institution of Engineers (India) Orissa Chapter and Orissa Renewable Energy Development Agency
Solar passive architecture	Hyderabad 9 January 1996	University College of Technology, Hyderabad
Solar architecture	New Delhi 13 January 1996	School of Planning and Architecture, New Delhi
Solar passive architecture	Coimbatore 29 January 1996	Tamil Nadu Energy Development Agency, Chennai
Solar passive architecture	Baroda 17 February 1996	Gujarat Energy Development Agency, Baroda
Solar passive concepts	Guwahati 22-23 March 1996	Association of Architects
Solar passive architecture	Nasik 15 March 1997	Architects and Engineers Association, Nasik
Solar passive architecture	Pilani 23 February 1999	Birla Institute of Technology and Science, Pilani

Table 4 Specialized workshops (representative)

Workshop/seminar	Place and date(s)	Organizer(s)
Solar passive architecture: concepts for hilly regions	Lucknow 29 March 1994	Central Building Research Institute, Roorkee
Energy-efficient lighting and daylighting in buildings	New Delhi 16 October 1995	TERI, New Delhi
Energy-efficient windows	SEC (Solar Energy Centre), Gual Pahari 1 March 1996	SEC, and Indian Institute of Technology, Delhi
Energy-efficient lighting design	New Delhi 29 November 1996	TERI, New Delhi
Software tools for building design optimization	New Delhi 26 May 1998	TERI, New Delhi

efficiency and energy, but in most cases do not incorporate the same in the building projects undertaken by them for various reasons. The objective of these courses is to bring the message home to the practising architects by providing them a comprehensive review on the subject. The courses are addressed by specialists in the respective areas including architects who are actively working on building energy efficiency. These courses educate them on recent trends on the subject and encourage them to adopt energy-efficient building projects. In many such programmes, training on handling relevant computer software is provided. Special workshops in the training programmes are also organized to deliberate on the DPRs prepared on new energy-efficient building projects under the demonstration programme of the ministry. Representative course contents for such type of programmes are presented in Box 1. These workshops have been found to be extremely valuable not only for training the architects but also for improving the designs of the buildings being discussed. The active participation of the architects helps in refining many intricate designs.

Matured and economically viable solar technologies such as solar water heaters, wherever required, are expected to be a part of such energy-conscious buildings. Use of solar water heaters is being encouraged by the government through a soft loan scheme (Bandyopadhyay 1998). The scheme is being implemented through the Indian Renewable Energy Development Agency – the financial arm of the ministry – and also through a few selected commercial banks (the Canara Bank,

Table 5 Specialized workshops (representative)

Workshop/seminar	Place and date(s)	Organizer(s)
Refresher/orientation course for architects	New Delhi 27-31 March 1995	Centre for Energy Studies, Indian Institute of Technology, New Delhi
Solar passive architecture concepts for cold climates	Shimla 12-16 September 1995	State Council for Science, Technology, and Environment, Shimla
Energy-efficient building design strategies	Bhopal 4-6 December 1995	Maulana Azad College of Technology, Bhopal, and Devi Ahilya Vishwavidyalaya, Indore
Application of passive building technologies in Indian context	Indore 20-24 March 1995	Devi Ahilya Vishwavidyalaya, Indore
Solar passive architecture (Orientation course)	Calcutta 22-27 March 1995	West Bengal Renewable Energy Development Agency, Calcutta and TERI
Solar passive architecture	Bangalore 23-25 January 1996	Karnataka State Council of Science and Technology, Bangalore
Solar passive architecture	Hyderabad 29-31 March 1996	University College of Technology, Hyderabad
Energy-conscious architecture	Aurangabad 22-23 March 1997	Maharashtra Energy Development Agency, Pune
Energy-efficient buildings through solar passive architecture	Bakoli, Delhi 19-20 March 1998	Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development, Bakoli
Passive solar architecture and building Technologies	Imphal 1-3 February 1999	Manipur Science and Technology Council, Imphal

Box 1 Typical contents of an orientation course for architects

- Energy-conscious architecture
- Passive building concepts
- Classification of climates in India
- Thermal comfort measurement and prediction
- Passive building in Delhi: a case study
- Thermal load calculations
- Evaporative cooling systems
- Daylighting
- Environment-friendly building: a case study
- Computer-aided simulation of thermal performance of buildings
- Earth-coupled building: a case study

the Union Bank of India, the Bank of Maharashtra, the Andhra Bank, and the Punjab and Sind Bank). Specific lectures on these technologies are organized during the courses. In order to train the officers of the banks implementing the soft loan scheme, separate training programmes are also being organized at different locations of the country. Apart from these, training courses are regularly organized in different parts of the country for the repair and maintenance of solar and other renewable energy devices and systems through state nodal agencies, regional test centres, and other professional organizations.

Conclusion

The training and education component of the SBP being implemented by the ministry for the last several years has already been successful in sensitizing people about the energy efficiency and resource conservation in the building sector. This has specifically contributed to the developments listed below.

- Awareness creation to a certain extent.
- A few teams of practising architects, who can offer energy-efficient building designs, have been developed.
- A few consulting groups specialized in building softwares are now available.
- A couple of solar buildings have been/are being constructed.
- Major sectors like defence, health, posts and telecommunication, education, and tourism are setting increasingly interested in the use of solar-efficient building design principles.

A few policy measures have also been initiated by number of state governments in this regard. For example, the state government of Himachal Pradesh has taken a decision that all future government buildings in that state would be constructed using solar building design principles. The governments of Haryana, Himachal Pradesh, Madhya Pradesh, Punjab, Rajasthan, and Dadra and Nagar Haveli (a union territory) have issued directives to their local bodies for using solar water heaters in all functional buildings in the state sector. The central government has constituted a committee to draft model building code for making solar water heating mandatory in all buildings which use hot water. The training and education programme, however, still requires to be continued with wider coverage, and with improved and more structured course contents. Available course materials need to be edited and published for wide circulation. Handbooks and softwares have also to be made easily available.

The field is still a developing one. With an increasing number of buildings being designed, constructed, and used, new information has continuously been generated. Performance evaluation of a few such buildings in different climatic locations is also planned. On the basis of the results of performance evaluation, it may be necessary to modify building design guidelines. The training inputs, therefore, require to be upgraded frequently. A building is a product of a process that starts on the board of an architect. It is, therefore, needless to mention that more and more architects need to be oriented to this concept. Also, a large panel of consulting engineers, specializing in the use and application of building software tools of energy efficiency, must be developed.

References

Mani A and Rangarajan S. 1982
Solar Radiation Over India
New Delhi: Allied Publishers. pp. 646.

Bansal N K and Minke G. 1988
Climatic Zones and Rural Housing in India
Juelich, Germany: KFA. pp. 287.

Gupta V. 1992
Architecture + Design. Vol. III.
Gurgaon: Media Transasia.

Bandyopadhyay B. 1997a
Solar Energy Centre and Solar Passive Architecture Programme in India
In *Solar Architecture & Planning*
Calcutta: Centre for Built Environment. pp. 287.

Bandyopadhyay B. 1997b
Solar Architecture
CII Renewable Energy Newsletter (October 1997): 1–2.

MNES. 1984–1998.
Annual Reports
New Delhi: Ministry of Non-conventional Energy Sources, Government of India.

Bandyopadhyay B. 1998.
Solar water heating
IREDA Newsletter 9(1): 17–23

Dulal Goldar

Department of
Civil Engineering,
Delhi College of
Engineering,
Kashmere Gate
New Delhi -
110 006
India

Curriculum of B. E. Civil Engineering course on renewable energy

Renewable energy education: current scenario and future projections
pp. 199-205

Abstract

The existing curriculum for B. E. Civil Engineering at the Delhi College of Engineering focuses on the following: (1) Humanities (English, Economics and Accounts, Technical Communication), (2) non-engineering (Physics, Chemistry, and Mathematics), (3) Allied Engineering (Engineering Drawing, Workshop, Manufacturing process, Engineering Geology, Electrical Technology, and Electronics), and (4) Engineering: Mechanics-based subjects (Solid Mechanics, Fluid Mechanics, Soil Mechanics, and Material Science), Structural Analysis and Design, Hydraulics and Irrigation, Transportation and Environment (like Air, Water, Solid Waste pollution and control).

India has plenty of RE (renewable energy) sources like biomass, solar, wind, hydro, and tidal energy. Curriculum development in B. E. courses for civil engineering is of great importance for the needs of the next century. Currently, the concept of energy and its various sources are not discussed in any of the subjects in civil engineering. Basic knowledge and available literature on RE is plenty, and it will be practical to educate civil engineers even from the users' point of view. Civil engineers must be informed about RE and its applicability in the planning and design stage in the following areas: heating, cooling, ventilation and lighting. Therefore, auditing energy requirement for the above four applications is vital.

The concept of passive solar architecture in a building or structure and use of energy can be optimized. Such an optimization technique in the energy sector will give overall economy of the project at hand. Subsequently, our country will benefit from RE education.

Introduction

Man has been using energy at an increasing rate for his sustenance, comfort, and well being ever since he came into existence on the earth a few million years ago. In the beginning of the civilization, he used non-conventional energy like wind, solar, and hydro. With Industrial Revolution, he started using conventional energy from fossil fuels like coal and petroleum converting heat to mechanical movements or electrical energy. Further, a new source of energy – nuclear energy came into existence after the Second World War to meet significant requirements of many countries including India. All these sources of energy created problems, they were not environment friendly and caused pollution. Thus, civil engineers are required to make an environmental impact assessment study. The reduction of pollution by the use of conventional energy and its optimal use for greater economy is of increasing demand in the 21st century.

India has plenty of renewable sources of energy like biomass, solar, wind, hydro, and tidal. Our geographical position has created diversity from north to south as well as east to west, but solar energy is plenty and the same is not being utilized to its full extent. The management of water resources must be to the fullest capacity for India, where floods and drought occur every year. Bounded by sea coast on the three sides, the country has a vast potential of energy from wind and tidal waves. Civil engineers need to provide ideas for a better civil life, sustenance, comfort, and well being, and therefore, education in RE is vital.

Building and energy

The requirement of energy for heating, cooling, ventilation, and lighting in buildings is to be known for overall economy. For bringing natural air and light to the working environment, civil engineers are required to design, develop, and test prototypes of pre-packed, made-to-measure building facade units for new and refurbished buildings. It will integrate natural ventilation, day lighting, and solar protection under intelligent local control and with PV (photovoltaic) power. The overall aim is to contribute to reducing energy consumption,. and consequently CO_2 emissions by:

- encouraging wider uptake of naturally ventilated and daylight in buildings, thus addressing the issue of optimal use of non-renewable resources,
- improving design and construction capability to deliver an improved quality of indoor environment for occupants and thus improve the productivity of the people in buildings, and
- developing RE powered multi-functional facade elements.

Major outputs from education in civil engineering for such projects will be:

- a pre-packaged application-specific building facade unit that integrates natural ventilation, daylighting, and solar protection under intelligent local control and with PV power, and
- an industrial controller (based on artificial intelligence techniques) to optimize the interactive operation and (when required) integrate with the energy system of the building.

Such projects can be focused on large commercial and public buildings where space heating, space cooling, and electrical lighting contribute significantly to energy use. Combining natural ventilation, solar protection, and daylighting in an optimum way will require the development of new intelligent control algorithm.

In addition, these will need to be integrated into any other energy or environmental systems in the building.

Building and life cycle assessment

A life cycle assessment is the compilation and evaluation of all inputs and outputs, and the potential environmental impacts, of a product system throughout its life cycle. Such a life cycle assessment will enable users to accurately quantify the impacts, and make decisions about the product from the environmental point of view. Calculations to permit types of structural systems and to incorporate a range of services options ranging from natural ventilation to full air-conditioning. The complete life-cycle energy requirements for all alternative structures and all the HVAC (heating ventilation and air conditioning) options are to be considered and periodic refurbishment and replacements for all alternatives are to be modelled for at least a 60-year life cycle.

Environmental management construction

The strategic review of environmental issues affecting the construction industry is important for the development of a sustainability indicator for civil engineering. The objective of this study is to provide guidance on the use and application of tools and techniques to manage and improve environmental performance. There is an increasing interest in the principle of sustainable construction, which includes relevant projects on

- the economic effects of environmentally sound technologies,
- social aspects of sustainable construction,
- improving consultation and communication with local communities during environmentally-sensitive development projects, and

- improving energy-efficient construction process and using renewable sources.

Curriculum development

For sake of brevity the details of existing curriculum of B. E. Civil Engineering is not reproduced here as the same is available in the form of a printed document from Delhi University or any other University. However suitable modifications are suggested below to incorporate RE education in a few cases.

1. CE-101 Humanities (to be included in essays)
   Man and energy; different sources of energy, e.g., food, fire, wind, solar, etc. used by man since life originated on the earth; industrial revolution and its impact on society and energy consumption; and fossil fuel and internal combustion engine, electricity and its applications, atomic energy and its applications, RE and its applications.
2. CE-112 Mathematics (to be included in differential equations)
   Basic heat equation and its applications to energy-related problems in buildings to estimate heating and cooling using conventional and non-conventional sources like solar energy.
3. CE-103 Physics I (to be included in topic of light)
   Solar light, PV cell, and use of PV cell for RE applications.
4. CE-113 Physics II (to be included under heat transfer)
   Solar energy option, solar radiation, solar heat collector, solar heaters, concentrating collectors, thermal energy storage, and solar pond.
5. CE-205 Fluid Mechanics: (to be included in a new chapter as compressible fluid – air)
   Wind flow, natural and artificial energy required for proper ventilation, use of wind energy as renewable source of energy, application for designing windmills and wind turbines.
6. CE-208 Building Drawing and Estimating (to be included in a new chapter)
   Passive solar architecture drawing of building/structures, estimation of energy requirement for heating, cooling, ventilation and lighting in buildings.
7. CE-209 Engineering Geology (to be included in as a new chapter)
   Geothermal source of RE, and requirement for tapping such energy and application.
8. CE-212 Electrical Technology (to be included in power system)
   Calculation for energy requirements in building for lighting, ventilation, heating and cooling in buildings; use of PV cell for electrical energy and its applications.

9. CE-213 Building Materials and Construction (to be included in a new chapter, recycled materials)
   Recycled concrete, new energy-efficient building materials, window panels, cladding, colour, and painting; construction with sustainable environmental issues, energy-efficient construction methodology, use of precast and prestressed units in building construction and in construction industry, and smart building.
   (to be included in ventilation)
   Natural ventilation, lighting, heating, and cooling using RE.
10. CE-305 Electronics (to be included in semiconductor)
    Development of PV cell, uses of PV cell power in different electronic control of smart buildings/structures, other application in lighting as well as use of different control system through digital computer interface in conservation of energy.
12. CE-304 Surveying II (to be included in a new chapter)
    Solar PV field instruments for geographic information systems and digital data transmission including electronic field book and graphical/digital image data transmission.
13. CE-312 Hydraulic and Hydraulic Machines (to be included in energy principles)
    Concept of energy requirement for laminar flow in ventilation, transition using non-conventional renewable source from compressible fluid flow like natural air.
    (to be included in hydraulic machines)
    Concept of tidal flow, use of this renewable source for generating energy like production of electricity from tidal wave, concept generator using tidal flow; concept of coastal/ strong wind flow and use of this renewable source for production, windmill and wind turbine for generating electricity.
14. CE-314 Environmental Engineering (to be included in purification of water/sewage)
    Use of natural renewable sources for purification of water as well as sewage; research in the area of photosynthesis, production of hydrogen fuel. Recycling the waste from industry and domestic waste for the production of energy; use of biomass for energy generation.
15. CE-315 Construction Technology (to be included in construction equipment)
    Use of solar-powered equipment for construction, communication, and environmentally managed construction; use of recycled materials in construction and locally available materials and avoiding spoiling of underground

water and use of recycled water heating and cooling from solar for different construction site.

16. CE-404 Design of Environmental Engineering Works (to be included in design of environment systems); and concepts of RE in design and construction of environmental engineering systems.
17. CE-405 Construction Management (to be included in planning)
Energy-efficient planning, use of energy auditing at every level of optimization of total use of energy in the life cycle of project; and concept of RE.
18. CE-411/412 Elective subject (to be included as new electives)
    - Energy audit, building and energy, energy engineering, and RE engineering.
    - Besides, many inputs of renewable education can be given in existing electives as listed below.
    - Building maintenance, environmental pollution and control, environmental sanitation, traffic engineering, water resources engineering, advanced building construction, and management technique for high rise buildings.
19. CE-415 Planning of civil works (to be included in planning)
Principles of passive solar architecture, use of RE sources for different applications in the practical project; use of latest computer software for energy auditing and passive solar application and retrofitting in existing structure.
20. CE-414 Project
Presently three students of B. E. Civil Engineering under the guidance of the author are working in the area of energy auditing of buildings taking into consideration heating, cooling, ventilation, and lighting. Such approach and awareness can be given to other students by different faculty members and in future, a Centre of Renewable Studies can be set up at the Delhi College of Engineering. In this way, a good number of civil engineering students will be graduating from the Delhi College of Engineering who will be provided expertise in the use of RE for better optimization of energy requirements of the country.

Conclusion

In the present paper, there are 20 civil engineering subjects discussed for possible inclusions in RE education. In addition to these, there are subjects for structural analysis and design in which structures related to RE can be discussed with possible geometry and loading for safe design. For example: design of solar heating tower, solar reflector/concentrator taking into account the heat load, and design of new types of cladding in smart buildings.

It also important to set standards, specifications, and minimum requirements for heating, cooling, ventilation, and lighting in a building for proper calculation of energy requirement in a building/structure. In this context, the Bureau of Indian Standards may be entrusted to set up a team of experts in these areas to set targets as per Indian Standards.

In this paper, the author has provided his own views supported by recent developments of RE subjects and different concepts of optimizing energy use. In developing an appropriate curriculum, the author's present inclusions are required to be discussed in a larger group of the Faculty of Civil Engineering. The author will soon propose a curriculum upgradation in civil engineering, in which, suitable modifications and introduction of RE-related subjects will be presented by him.

Solar Energy
Research and
Training Centre,
Naresuan
University,
Phitsanulok
65000,
Thailand

Herbert A Wade

Human resource development for solar energy

Renewable energy education: current scenario and future projections
pp. 206-220

bstract

Most of the SPV (solar photovoltaic) projects are intended to provide basic electrical services to rural areas as well as to provide training to installers and technicians directly involved in the project. The human resource development has become essential for successful rural electrification through solar energy. Although the basic training provided does allow adequate quality installations and, at least for a start up period, reasonable maintenance, in the long term such projects rarely succeed due to a lack of understanding of the process of solar-based rural electrification. For solar-based rural electrification to be a success, training and education must be provided at all levels of the electrification process from high-level government policy makers to the users themselves.

Concentrating on the technical aspects of solar electrification is important, but business skills for the many small businesses that must be associated with a distributed electrification system like solar must also be developed. Government officials need to understand clearly what solar energy can and cannot do and must have the necessary skills to decide whether or not solar energy is the best approach to rural electrification in a specific area. Policy makers must have an understanding of the economics of solar, the requirements to make solar electrification sustainable, and the appropriate milieu needed for its development. A further requirement is that this human resource development must take place within a relatively short period and in a manner that leads to rational and progressive development.

The training and education process requires effort at all levels of the educational system including the development of specialized educational tools and arrangements to meet the needs of government officials and users. For sustainable and

rational development of solar rural electrification, a comprehensive programme of education at the vocational level for technical skill levels from basic through advanced solar technology, university level programmes for engineers and future policy makers, programmes to assist in the education of small solar businesses in management and financial skills, and introductory course modules at the primary and secondary levels are needed. Publications, workshops, and seminars directed at policy makers and government officials are also needed.

Introduction

For hundreds of years, solar energy has been used for water heating, crop drying, and building heating. In the last 40 years, it has been further applied to making electricity and to cooling of buildings. The technology is well developed and well understood. However, the application of solar energy has not had significant impact in the energy balances of the world. In an attempt to explain this situation, lists of 'barriers' to the application of solar energy are often published which include cost, availability of materials, and financing. While it is certainly true that such barriers exist, it is also true that for many applications, particularly in rural and remote areas, solar energy is the least-cost option; the materials are readily available on the world market if one knows where to get them from. As the least-cost option, financing should be more available than for conventional energy sources.

However, most of the barriers relate to a lack of knowledge, training or skills in the people involved at all levels. While solar energy should be automatically considered as an energy source for rural and remote areas, country energy planners rarely include it in their analyses. Electricity supply authorities place remote areas on long waiting lists for grid extensions and never realize that solar is a viable - and usually low-cost - alternative which can be installed immediately. Businessmen sell solar systems but do not arrange for the provision of spare parts and maintenance and then wonder why their business fails. SPV maintenance personnel replace a battery without checking to find out why the earlier battery failed and then blame the battery manufacturer when the new battery fails after a short time. Users of solar systems overload them and wonder why their service is poor. So when the final analysis is made, the primary barrier is mostly a human one based mostly on ignorance about solar energy and can only be overcome by a concerted effort to educate, train, and enlighten the people involved all the way.

Therefore, a key factor to the development of solar energy is the human resource development. To state it more clearly, what is needed is training and education for all persons involved in promoting, applying, and using solar energy and provision of the environment needed for that training and education to be put to proper use.

Structure for successful rural electrification using solar energy

To understand what kind of human resource development is needed, the first step is to determine what activities must be carried out to put solar energy into effective use.

Energy planning Solar energy, like any other energy source, has characteristics, which place it economically and technically into particular categories of use. In general, solar is best suited to supply small amounts of high-quality energy in areas where conventional energy supplies are expensive or supplies are unreliable. Skills in assessing the energy needs of individuals and communities are necessary and an understanding of just what solar energy can do effectively and cannot do economically is required. Currently, it seems that two incorrect approaches to the application of solar energy commonly exist in government planning circles: (1) solar is assumed to be too good and is forced into situations where it cannot perform well and (2) solar is assumed to be good for nothing and applications where it is the best economic and technical choice are ignored. The reality is, of course, in between and planners need to know when solar makes sense and when it does not and make their plans accordingly.

This means (1) the skill and understanding of the economics of various energy supply options including solar, (2) an understanding of the technical capabilities of solar systems of various types with knowledge of their cost of installation and operation, and (3) the skills to perform an analysis which compares each supply technology on a realistic basis. It also means skill and training in needs assessments. Many times, the actual energy needs of people in remote areas are assessed incorrectly. Assumptions about the availability of cash in those areas and the desire of those people to have energy services are often incorrect and as a result, the planning decisions made are also incorrect. This is usually the result of planners coming from an urban environment and having lost touch with the realities of existence in rural areas. At least in South-east Asia, it appears that rural cash availability is much higher than usually estimated and people place energy, particularly lighting and entertainment appliances, at a higher priority for that cash than is usually estimated. The problem can usually be traced to poor skills in needs assessment surveys and analysis, a problem which can be corrected by training and education.

Design The design of solar systems for electricity supply, hot water production, and crop drying is not an arcane art. The system design process is well defined, well documented, and technically straightforward. Unfortunately, a large number of poorly-designed solar systems continue to be installed and such systems are doomed to perform poorly. Even supposedly knowledgeable people, particularly representatives of equipment suppliers, too often provide poor designs more intended to minimize cost than to provide adequate performance over the long term. For solar progress, a cadre of people associated with the government, power authorities, and private solar businesses with the training and capability to create designs appropriate to the specific needs of each user must be trained.

Material selection and supply

Suppliers are in business to sell equipment and cannot be relied upon to relate the problems with the equipment being supplied. Yet most components for solar systems are selected on the basis of supplier recommendations. What is not generally realized is that there are several distinct markets for solar products besides the rural developing country market and products designed for one market may not be suitable for another. Because of the visibility (and profitability) of the market to developed country manufacturers, a high percentage of solar equipment imported from developed countries has been employed for providing energy for remote vacation homes in the developing countries. As a result, a considerable fraction of the equipment which is available in the market place is simply inappropriate to use in remote areas of developing countries. A prime example is that of battery charge controls for SPV electricity systems. Many of these include such frills as an internal programmable microcomputer, LCD screens with instant indication of the system status and lots of indicator lights to show what the control is doing. Unfortunately, they also include unreliability in remote areas of the tropics, great difficulty in diagnosing system problems in the field, and impossibility of local repair when frequent failures occur. Yet, suppliers endlessly promote the 'latest and greatest' components to developing country markets even though they were intended for a very different market niche and often older; proven designs perform much better for the remote, tropical user. Indeed, it is common for even large, reputable manufacturers in developed countries to create designs and aggressively market them to developing countries without ever actually trying them in the field. Specific examples of this include PV (photovoltaic) battery controllers as well as high efficiency DC (direct current) lights used with PV systems.

The selection of proper components for the solar system to fit the environment of the installation site is critical to the success of solar systems and education and training in the proper specification and purchasing of those components is very much needed.

Installation services

If the installation of a solar system is not done correctly, the system cannot work properly and its life will be short. Yet the poor quality of installation remains one of the leading causes of system problems with solar. Earlier, this was because people did not know how to install. Today, the problem is different. Programme managers generally provide training, or at least clear instructions on proper installation. The problem now is one of management. Installation teams may have proper training in how to do an installation but are not provided with training on how to manage their work. So teams often have improper tools and those they have are often used incorrectly. They regularly run out of proper material and use inadequate substitutes and supervision from the programme office is poor or nonexistent. Programme managers need training in remote system installation support and management as much as installers need training in the actual installation itself.

Maintenance services

The long life of solar systems, like any other technical system, is directly dependent on the quality of maintenance for the system. Although there are relatively few people who are properly trained in solar system maintenance, the reality is that the people managing the solar projects are themselves usually unaware of what is required for solar system maintenance. They often assume that the users of the system will be competent (and interested enough) in maintenance to do it right or that equipment suppliers will be interested in taking the risks which come from making the complex and expensive arrangements necessary to provide maintenance to remote users at an acceptable cost.

Project managers need to be educated about solar maintenance requirements and need to understand that the advertising claims of 'no maintenance required' and 'all maintenance can be carried out by the user' are generally false for remote solar installations in developing countries. It is true that maintenance is not complex nor is it required more often than every month or two, still maintenance is required and if it is not carried out properly the system will not perform well.

Finance

A great deal of thought and effort by experts in the solar development community have gone into the development of 'innovative financing' arrangements for solar. This has been done because of the perceptions that high first cost solar systems need to be sold directly to users and financing arrangements for solar systems in rural areas cannot be made through local financing.

Yet, in most rural areas of the developing world, there are many formal and informal financing arrangements made to individuals and households for agriculture, loans for seed or irrigation, for example, services which are paid back at harvest time. Few rural families operate their households without obtaining credit and paying debts to cooperatives, local stores, rich families in the village, rural banks or other households in the family. That many of these financing arrangements could also be mobilized for the finance of solar systems seems reasonable provided the person or organization providing the finance understands about solar, the real cost of purchase and operation of solar systems, and what value remains in the solar system once installed should repossession be necessary.

Education needs to be provided to donor agencies, international banks, and other organizations that finance solar. The strong mindset that solar systems are a commodity that should only be sold to users needs to be weakened. There has been considerable long-term success in providing solar electrical service for a periodic fee where ownership and maintenance is taken care of by a service company. Such arrangements automatically take care of both the problem of rural families finding finance for purchase and the provision of proper maintenance on the systems. It seems strange for international banks and governments to create Byzantine, subsidized financing arrangements for a relatively few rich rural households to purchase solar when sufficient cash is available in many more rural households to pay the full cost of capital, maintenance and profit to a service company which can spread the cost over decades instead of just a few years.

Education needs to be provided to cooperative managers about solar energy. For a cooperative to purchase solar systems and then rent them to their members for a fixed monthly fee could be profitable to the cooperative. Such an arrangement would provide a good service to each member, and would not involve problems with collection since the cooperative is in a position to collect directly from the members who sell their goods through the cooperative.

Education needs to be provided to electrical power authorities about integrating solar energy into their utility structure by purchasing, installing, and providing maintenance service for solar equipment in remote areas and collecting a periodic fee based on the cost and service provided.

Business skills

Solar energy related businesses are essentially rural-based. That is where the market is and that is where they must succeed. However, rural areas are not places where people with business sense and management skills are commonly found. Record keeping is particularly poor in most rural businesses and it is certainly true that the future of a business depends strongly on knowledge of its past as viewed dispassionately through its records. Mechanisms for the rural businessman to separate himself from the communal and family obligations that he individually has are also necessary. It is all too common to find rural businesses failing because the people who hired are generally from the family itself or friends instead of competent personnel extending extensive credit (or worse just giving away store goods) to family members and neighbours. Education must go not only to the entrepreneur but also to the family and also the community.

External support

Although it is usually assumed that training and education always flow from developed to developing countries, in the case of solar energy applications for developing countries, it must also flow the other way. The truth is that solar project managers in developing countries have far more experience and knowledge about what works and what does not than developed country 'experts' and international suppliers of solar equipment. One of the most serious problems within the solar industry is the almost total lack of timely feedback from field users to suppliers and manufacturers. Manufacturers do not intend to sell equipment that is a poor choice for developing country rural applications yet they continue to do so. The reason is that no one actually tells them that their equipment is not up to the mark. This is partly because programme managers sometimes do not follow up themselves but more often because there is simply no effort to educate the suppliers. One controller 'specifically designed for the developing country market' by a major manufacturer had connections that were too small for the wires needed in the systems, had circuitry that was easily damaged by nearby lightning strikes, and got too hot in the tropics for long life of the semiconductors used. It worked great in the laboratory and in the field tests made in the backyard of the manufacturer's plant. When actually used in a developing country rural climate, it was far from satisfactory. In that particular case, feedback was provided to the manufacturer and the design was quickly changed to better meet the users' needs, but regrettably that is not common.

Donor agency personnel responsible for solar projects need to be educated about the realities of the rural existence. They need to be taken to the rural area, walking over jungle trails for hours or days to reach the site and not to drive to some nearby 'show village' to be with the 'rural people'. They need to be with the people they wish to assist. They need to see for themselves the difficulty of supplying materials and technical services to those sites. Without that personal education, it is all too easy to wave off the problems and assume that things must not be too much of a problem since, after all, people do live out there. Very few donor agency personnel have a real concept of either a low cash, yet substantial rural economy based on subsistence and barter or the priority which rural people will place on spending their limited cash on such things as solar electricity. Even government officials need to be educated about economic conditions in remote rural areas since they do not often realize that a high percentage of cash in such rural areas is discretionary and as a result families with as little as $20 a month cash income may be willing to spend $10 a month on solar if that is their priority.

Training support

It seems that educational institutions are often way behind the curve of technology. Computers and software used in schools are often many years behind those used in business and government. Courses and curricula incorporate change slowly and usually the information passed on to the student is years behind the latest techniques found in the world outside. No doubt this is because the knowledge and skills of the staff change slowly and partly because it is expensive to make frequent changes in equipment, texts, and facilities.

Yet, it is these same educational institutions that must be in the forefront of training and education for solar technology. Therefore, there must be a well-defined and consistent effort on the part of governments and donors to upgrade the skills of teaching staff at educational institutions, assist in the integration of solar into existing courses and curricula and to provide adequate solar equipment and facilities for training.

It should be noted that when this is done, sometimes the emphasis is in the wrong place. Developing countries do not yet need solar researchers, they need solar engineers and technicians. Frequently, universities receive large grants from the government or external donors for improving solar research capabilities but vocational trade schools cannot even find texts suitable for teaching technicians. It is the application areas of training that are needed, not the theoretical.

evelopment of skills

Resources in the developing countries are limited. The existing technical skill base for solar energy development is usually small, and the demands on educational institutions for all areas of technical development are great and rapidly growing.

For the development of human resources for solar energy, there needs to be a rational plan, which incorporates as many local information resources as possible. While independent development of any single training resource for solar energy is not likely to be a waste, it is unlikely to have more than limited effect without coordination with the development of other resources. The real need is to develop almost simultaneously a wide range of educational and training services to improve the understanding and skills of high government officials, civil servants, power utility management, local solar businesses, solar designers, manufacturers, installers, maintenance personnel, solar system users, and the general public. To be effective, it needs the involvement and coordination of the efforts of a wide range of institutions and services, which range from postgraduate level degree programmes to articles in the local public media.

Educational institutions

All levels of education should be involved in solar energy information and education. For the developing countries, probably the most important area of formal education is in the vocational trade programmes of high schools and trade schools. These institutions are in the business of training people to do practical work and should be specifically targeted in the development of training for solar energy installers and maintenance personnel. With their existing programmes of electrical trades training it is relatively easy and inexpensive to add the concepts of solar energy and low voltage DC system installation and maintenance to their curricula and the necessary speciality facilities for solar training. The development of a fully functional, permanent solar trades training facility can be made for a cost that is less than that incurred in sending four or five persons for overseas training in a developed country and the result is more likely to be locally relevant and consistent and at the same time reach a much larger number of people.

At the undergraduate university level, it is generally not practical to create full study programmes in solar energy. However, it is certainly reasonable and realistic to incorporate individual courses in solar energy and solar engineering within an electrical or mechanical engineering curricula. With the increasing use of solar energy at all levels of energy supply, graduate electrical engineers without any basic training in solar theory would greatly benefit by learning elementary solar design.

Although not as high a short-term development priority as trade schools and universities, the creation of short but informative solar education modules for high school and primary school students can be very beneficial in the long term leading to better understanding and more interest in solar energy by the general populace.

Solar suppliers Persons involved with solar projects should make specific arrangements to provide local solar businesses and component manufacturers with documented feedback, both positive and negative, about solar products in use in their projects. Without such a feedback, suppliers of solar components cannot improve their products to meet local needs.

For those few component suppliers too arrogant or ignorant to accept that feedback and make the needful changes in products, a more emphatic form of education needs to be imposed: simply stop buying their products through the preparation of purchase specifications which meet the real needs of the local situation and thereby lock out suppliers not willing or able to comply.

For local businesses supporting solar development, business training in management, record keeping and bookkeeping is valuable, particularly to newly formed rural businesses. That training can be provided through extension training programmes, correspondence courses, 'roving' workshops, and evening education courses.

Overseas training In the early years of solar development, the need to send a few people overseas for special training will remain, since local training capability takes some time to develop. There will continue to be many overseas training opportunities in solar energy ranging from highly specific workshops of a few days to multi-year graduate programmes.

Not only are there many types of overseas training and education available, they vary widely with relevance to the needs of the recipient country. For training offices unfamiliar with the needs of solar development, it is generally difficult to prejudge the appropriateness of overseas training opportunities and too many end up merely as a well-paid junket to a foreign country for the students. In selecting overseas training programmes, the underlying need of practicality must be kept in mind. The course should first of all be directly and immediately relevant to the country's needs and be designed specifically for persons from developing countries whose native language is not the language in which the course will be presented.

Project training Training included as part of project implementation is vital but insufficient. Vital because each project has specific requirements for installation and maintenance, and for success, the people doing the installations and maintenance need to be trained in those specific areas. Training included as part of projects is generally insufficient because even if the training is of excellent quality it usually does not extend beyond the immediate time limit of the project implementation. As a result, there is generally no training available for those persons replacing the original staff and as staff changes take place the quality of service falls and the project fails.

Overseas attachments in other developing countries

As mentioned earlier, some developing countries have more relevant experience and practical capability in solar development for rural areas than developed countries. Where language and politics allow, the attachment of personnel to more advanced developing country solar programmes can be very beneficial, providing effective on-the-job training. Generally, attachments of more than one month or less than one year seem most effective. Little can be learned about the details of a project in less than a month and a little extra is usually learned beyond a year. Probably three to six months of attachment is most cost-effective. It should be noted that attachments to solar organizations in developed countries have not been particularly successful for developing country personnel since the application situation and technology tend to be very different, and therefore, less relevant.

Maximizing effectiveness of human resource development efforts

Simply establishing a budget, finding a teacher, and providing a venue is not enough to ensure effective training, education or information transfer though that is often what is attempted. There are a number of tricks of the education trade, which can be used to improve training effectiveness. Some of them relevant to solar energy training are listed below.

- *Time the training properly.*
  It is useful to note that the same effort in training and education can have very different results according to its timing. If the educational process takes place long before the information can be used by the student, e.g., installation training at the beginning of a project months before any installations are actually made, its effectiveness is low. If the same training is carried out immediately before the information being provided is put to use, it is effective. If the same or very similar training is carried out at the beginning and again well into the project (but before project completion), the effectiveness is the greatest. This process of training reinforcement clearly increases the

understanding of the students because secondary (refresher) training comes after some on-the-job experience has been gained and the information can be directly related to that experience.

- *Let the trainees make mistakes; then help them correct them.* Mistakes are necessary for successful learning because the trainee remembers the mistake and having to correct it than training work that has gone smoothly. That is why an on-the-spot expert advisor is rarely successful in preparing the local counterparts for their jobs. The advisor keeps them from making mistakes and makes the process seem effortless and easy, which is far from what they find when they are. The essence of training is problem-solving and having the professor always insuring that your exam questions are correct is not very beneficial to the student. Of course, making mistakes is not educational if the mistakes are not pointed out and the correct action shown. So the most effective form of external advice seems to be to have the expert on hand, periodically, some 5%–10% of the time (two weeks every six months, for example) to check on decisions already made by the local counterparts and to point out problems resulting from those decisions and help the counterpart get back on the track before things get out of hand. In the period between visits, communication by fax, phone, or where possible, e-mail can keep the information flowing between the advisor and the counterparts, but it is the counterpart who is truly making the decisions and is taking the responsibility for them. Yes, that process is inefficient in the short term and the time to get things done is usually longer than if there is an expert advisor on hand, but at least when the expert advisor is gone, the project is much less likely to collapse.
- *Wait until the results of a project are clear before using it for a reference.*
  Solar projects with reasonable technical designs rarely give significant problems within the first year or two. Yet, the great majority of government and donor funded solar projects end monitoring and expert advisory services within a year of the project's completion. This is one reason why so many published project reports are so glowing about the successes when a visit a few years down the line finds a very different situation. To really know whether or not the project is truly a technical and economic success, five years should be the minimum for monitoring and some minimal advisory support is

valuable for as much as ten years from the commencement of a substantial solar programme. Unless the longer term monitoring is done and published, equipment suppliers, solar designers, and project designers tend to continue to repeat the same mistakes and their development is stagnant. Also, unless some expert advisory support is available over the long term, project managers and technical support personnel can easily make errors that are not serious in the short term but destroy the project eventually – such as a decision not to disconnect users of solar electricity systems who do not pay their fees, an action which usually results in the economic collapse of the project a few years later.

- *Trainers have to be at a higher skill level than that required of the trainees.*
  Persons are not very effective in training others requiring the same level of knowledge. That is, a field technician should not be the exclusive trainer for his own replacement, there should be a more knowledgeable trainer doing the primary training to impart the theoretical understanding of the subject. Otherwise the training tends to become a checklist of dos and don'ts with little understanding of the processes involved and the trainee is unprepared when a new situation not covered by the 'checklist' arises.
- *Once is not enough.*
  People remember and understand best when information is presented more than once and in different ways. Persons can to be trained in the same activity through reading, writing, handling equipment, and hearing. Along the same lines, persons need periodic repetition for best retention. It seems that at least yearly reinforcement of training is important for the retention of skills, particularly in situations, like solar electricity systems, where improper system maintenance or an inadequate design may not cause immediate problems but over a period will cause system failures.
- *Trainers usually learn more in providing training than the trainees.*
  A final point is that one of the best ways to increase real understanding of a subject is to try to teach it to someone else. Therefore, it is excellent practice to require higher level technical staff to develop and provide formal training courses to lower level technicians in their area of responsibility.

Conclusion

Human resource development for solar energy is not just training and education of technicians directly involved in applying solar energy technologies. Almost every person who has any contact with solar development has some need for increased knowledge and capability about solar energy. If solar energy development is to proceed rapidly and rationally, the present *ad hoc* approach to training, education, and information transfer is not sufficient. What is needed is a well-integrated and well-timed approach to reach everyone involved in solar energy development.

Central Arid Zone
Research Institute,
Jodhpur - 342 003
India

N M Nahar*, K P Thanvi

Role of renewable energy education in the development of arid regions

Renewable energy education: current scenario and future projections
pp. 221-226

Abstract

The Indian tropical arid zone, occupies a large area spread over western Rajasthan, North Gujarat, south-western parts of Haryana and Punjab, and parts of Andhra Pradesh and Karnataka. Despite having rich flora, fauna, a variety of minerals, high velocity winds, and intense solar radiation, the region's development has been slow due to several reasons.

The fact is that population density in this region is quite low and people live in small hamlets. Electrification of the scattered villages has not taken place, nor is expected to in the near future. The region, however, offers enormous potential for the utilization of SPV (solar photovoltaic). For the efforts of the state nodal agency to be successful, there is need to include formal and informal education on renewable energy in all syllabuses at different levels. Non-government offices can play a significant role in spreading the importance of renewable energy devices, through audio-visual aids and adult literacy programmes. Renewable energy education components suggested by the author in this paper are expected to aid the development of the arid region in India.

---

* Author for correspondence

Introduction

The Indian tropical arid zone, occupying an area of 320 000 km^2, is spread over western Rajasthan, North Gujarat, south-western parts of Haryana and Punjab, and parts of Andhra Pradesh and Karnataka. However, the major part (76%) of this zone lies in western Rajasthan and covers 12 districts. This region is endowed with rich flora and fauna and a variety of minerals, and receives high velocity winds and intense solar radiation. Still, the region's development is very slow due to low productivity of land, frequent occurrences of drought, locust menace, low rainfall, poor quality of underground water, low levels of literacy, lack of conventional energy sources, and poor availability of power. But arid regions are fortunate to be blessed with abundant sources of renewable energy, namely, solar energy, wind power, and bioenergy.

Renewable energy potential

Solar energy

Solar radiation outside the earth's atmosphere remains practically constant at 1.353 kWh/m^2. The eccentricity of the earth's orbit leads to a variation of about ± 3%. Radiation received at the earth's surface is reduced below the extraterrestrial value considerably due to reflection, absorption, and scattering of radiation in the earth's atmosphere. Therefore, the total solar radiation received at the earth's surface consists of direct and diffuse radiations.

The arid regions receive plentiful solar radiation. It is measured regularly in Jodhpur and charted here in Table 1 (Mani 1978). Jodhpur receives 6 kWh/m^2/day global solar radiation and 1.981 kWh/m^2/day diffuse solar radiation on horizontal surface, and 6.272 kWh/m^2 direct solar radiation at

Table 1 Solar radiation at Jodhpur (kWh/m^2/ day)

Month	Global	Diffuse	Direct normal	S.S. (hrs.)
January	4.715	1.138	7.238	9.1
February	5.565	1.362	7.420	9.1
March	6.540	1.771	7.354	9.0
April	7.233	2.336	6.725	9.5
May	7.545	2.683	6.324	9.8
June	7.068	3.058	4.985	9.2
July	5.979	3.385	3.298	6.9
August	5.544	3.208	3.126	6.8
September	6.101	1.878	6.020	9.4
October	5.827	1.218	7.604	9.7
November	4.903	0.808	7.719	9.4
December	4.432	0.931	7.448	9.0
Average	5.954	1.981	6.272	8.9

Source Mani (1978)

normal incidence. The average daily duration of bright sunshine is 8.9 hours. The solar radiation at other places is estimated (Mani 1982) and shown in Table 2. Jaisalmer receives the maximum radiation of 6.27 kWh/m^2/day. Jodhpur, Barmer, and Jaisalmer districts have been declared solar enterprise zones. Solar thermal and PV power stations are being set up there.

Table 2 Computed global solar radiation (kWh/m^2/day) at different arid stations of Rajasthan, Gujarat, and Haryana

State and station	Winter (December-February)	Summer (March-May)	Monsoon (June-September)	Post monsoon (October-November)	Annual average
Rajasthan					
Jodhpur	4.92	6.93	6.43	5.52	5.92
Bikaner	4.67	6.93	6.43	5.52	5.92
Jaisalmer	4.84	7.36	7.39	5.52	6.27
Barmer	4.92	7.36	6.82	5.57	6.16
Hanumangarh	4.20	6.33	6.10	5.60	5.55
Gujarat					
Bhuj	5.19	6.85	5.73	5.65	5.85
Haryana					
Hissar	4.28	6.52	6.02	5.76	5.64

Source Mani and Rangrajan (1982)

Wind power The monthly wind speeds at the main stations are shown in Table 3 (Mani 1992). There is high potential of wind power pumping water in Jodhpur, Barmer, and Jaisalmer districts. The average wind speeds in Barli and Phalodi in Jodhpur district at a height of 10m are 4.76 and 5.25 m/sec respectively. The maximum speeds are 7.09 and 8.70 m/sec and the minimum speeds are 3.09 and 3.16 m/sec respectively. The average wind speeds in Pachpadra, Bhadka, and Derasar at a height of 10 m are 3.49, 4.51, and 3.46 m/sec with a maximum 6.73, 7.86, and 6.35 m/sec, and a of minimum 1.32, 2.27, and 1.48 m/sec respectively. In Khodal and Jaisalmer at a height of 10 m, the average wind speeds are 5.28 and 5.45 m/sec, with a maximum of 8.88 and 9.34 m/sec, and a of minimum 2.74 and 2.74 m/sec respectively.

Biogas The animal population in the arid region is 1.5 times the human population. Therefore, animal waste is available in plenty. The estimated animal waste in Rajasthan, Punjab, Haryana, and Gujarat is 11 168, 4442, 20 829, and 10 206 million tonnes per year respectively.

Table 3 Wind speeds (m/sec) at various stations

Month	Barli	Phalodi	Pachpadr	Bhadka	Derasar	Khodal	Jaisalmer
January	3.93	3.57	1.62	2.67	2.05	3.36	3.32
February	4.24	4.18	2.17	3.34	2.61	4.04	3.86
March	4.39	4.77	2.62	3.68	2.77	4.53	4.52
April	4.48	4.96	3.32	4.53	3.21	4.98	4.64
May	5.84	6.71	5.32	6.59	5.01	7.22	6.91
June	6.76	8.08	6.55	7.37	5.89	8.44	8.68
July	7.09	8.70	6.73	7.86	6.35	8.88	9.34
August	5.25	7.18	4.62	5.57	3.90	6.73	7.30
September	4.50	6.36	3.82	5.05	3.97	6.21	7.32
October	3.09	3.82	1.61	2.73	1.48	3.29	3.80
November	3.56	3.16	1.32	2.40	1.60	2.98	2.74
December	3.67	3.08	1.45	2.27	1.55	2.74	3.13
Annual average	4.76	5.25	3.49	4.51	3.46	5.28	5.45

Source Mani (1992)

Importance of renewable energy education

Population density in arid regions is quite low. People live in small hamlets. Therefore, many villages are not electrified. In fact, there is no hope of electrification for another 20 years. In such a scenario, photovoltaic electrification is the only solution. Considering this, REDA (Rajasthan Energy Development Agency) has installed over 2000 SPV street lights in arid areas of western Rajasthan. Solar lanterns and domestic PV systems are also gaining popularity. But the downside is that people lack know-how regarding upkeep of renewable energy systems. Consequently, these systems are often out of order. Most of the SPV street lights are out of order due to negligence in battery maintenance e. g. periodic topping up with distilled water. Similarly solar cookers are becoming popular but people misuse them, and village technicians are not yet trained to repair them. A solar cooker differs from a wood/kerosene stove in that one has to put a precise quantity of water in the cooking utensils with the food. This quantity differs for different cooking materials. If water is not adequate, the food will not cook properly and that will undermine the image of solar cookers. Similarly, biogas plants do not work if there is a crust formation or more percentage of CO_2 in the gas.

Rectifying these defects does not require any major expertise. Therefore, there is great importance of formal and informal education on renewable energy in arid regions, which are scarce in conventional energy resources.

Renewable energy education at various levels

Primary level

Most children in arid regions drop out of school after passing class V. Therefore, the science syllabus for class V should be enhanced by adding a chapter which elaborates the importance of conservation of conventional energy sources and the use of solar and other renewable energy sources, e.g., solar cookers, solar lanterns, biogas plants, etc.

Middle level

The syllabuses of middle level classes, i.e., class VI–VIII, should have one chapter each on solar energy, wind power, and biogas.

Secondary level

In secondary and higher secondary classes, i.e., class IX–XII, the subject should be dealt with in more detail. The different applications and their principles, the performance and maintenance of different devices, e.g., solar cookers, solar dryers, solar lanterns, solar domestic SPV systems, solar water heaters, biogas plants, and wind mills can be explained.

Polytechnic level

In polytechnics, the mechanical engineering discipline could include a course on the design, fabrication, and testing of different renewable energy systems.

Non-formal education

Week-long training should be given to village technicians for the upkeep and maintenance of solar lanterns, street lights, solar cookers, biogas plants etc.

Suitable audio-visual aids illustrating the maintenance of renewable energy devices should be shown to villagers by non-government offices and under adult literacy programmes.

Conclusion

Renewable energy education should be strengthened by incorporating the importance of renewable energy devices in all syllabuses, from primary school to higher levels, including polytechnics and engineering institutions. Non-government offices should also be involved in spreading the importance of renewable energy devices, through audio-visual aids and adult literacy programmes. Training rural artisans could help them in income generation. Poor villagers and farmers could use solar energy devices, e.g., solar dryers, solar candle machines, large size solar cookers, etc., for supplementing their incomes. Renewable energy education in arid regions will thus aid the development of arid regions, which are scarce in conventional energy sources.

References

Mani A. 1978
A handbook of solar radiation data
New Delhi: Allied Publishers.

Mani A and Rangrajan S. 1982
Solar radiation over India
New Delhi: Allied Publishers.

Mani A. 1992
Wind Energy Resources Survey in India-II
New Delhi: Allied Publishers.

Session IV

Media and advanced electronic technologies in the promotion of renewable energy education

■

Electronic communication technologies for
renewable energy education
Christopher Gronbeck

■

Education television as a medium for
renewable energy technology propagation
D Mutharasu

■

Teaching aids for lectures on renewable energy sources -
an example from Slovenia
Saso Medved

■

Press as a development tool in publicizing
renewable energy education and knowledge
S Ganesh

■

Concept and design of photovoltaic systems with PV-CODE:
a dedicated computer program for teaching and
research purposes
J C Vernetti dos Santos

Media and advanced electronic technologies in the promotion of renewable energy education: summary

Renewable energy education: current scenario and future projections
pp. 229-230

Chairpersons
- Prof. R L Sawhney
  Devi Ahilya Vishwavidhalaya, Indore, India
- Dr Shahida Rafique
  University of Dhaka, Dhaka, Bangladesh

Rapporteurs
- Dr Jai Prakash
  Delhi University, New Delhi, India
- Mr Shirish Sinha
  TERI, New Delhi, India

The session highlighted the roles of four mediums – multimedia, the Internet, the television, and the press – in promoting REE (renewable energy education).

The first presentation from CREST (Center for Renewable Energy and Sustainable Technology), Washington, DC and was made by Mr Christopher Gronbeck, who laid emphasis on the use of multimedia and the Internet in REE. He gave an example of the Renew India web site, which provides information on renewable energy technologies in India and their status. He briefly mentioned other software packages like The Sun's Joules, which were on display in the TERI premises. He explained how system sizing could be done in households using software like the SolarSizer. The presentation's overall emphasis was integrating electronic media with conventional teaching methods.

The second presentation by D Mutharasu from Madurai Kamraj University, was on television as a medium of REE. The University has developed a series of educational films on solar drying processes and solar cookers, which they use for creating awareness among the rural masses, the commoners, and housewives.

The third presentation, by Dr Saso Medved, was on teaching aids for lectures on renewable energy sources and used examples of various methods being used in the University of

Ljubljana, Slovenia. Dr Medved basically spoke about three software packages used for educating students – Eemultimedia, Solar Professor, and Solar Engineer – each targeted at a distinct level of students.

The last presentation by S Ganesh, a freelance journalist, was more on the role the press can actually play as a development agency in REE.

Centre for
Renewable Energy
and Sustainable
Technology,
1020 NE 68th St.
Seattle
WA 98115, USA

Christopher Gronbeck

Electronic communication technologies for renewable energy education

Renewable energy education: current scenario and future projections
pp. 231-245

Abstract

Renewable sources of energy are crucial to a sustainable global future. Access to clean and reliable energy can improve the quality of human life in villages and cities, while also benefitting local and global ecosystems.

Recent advances and long-term trends justify optimistic thinking about RE (renewable energy), but if the full potential of renewables is to be realized then it must be acknowledged that technical and economic feasibility do not comprise a sufficient condition for a transition to renewable sources of energy. Education is also critical to success.

Education must embrace a spectrum of community members, and must occur even at every stage of the transition from awareness to design to installation to maintenance to evaluation. Even one weak link in the educational system can jeopardize the entire process.

Electronic communication technologies, such as the Internet and multimedia software, have important roles to play in educating the whole gamut of people involved. Such information systems are especially effective in addressing global economic and environmental concerns that inherently transcend political and cultural borders.

There are many electronic educational resources on RE today that address the needs of a diverse audience. These pioneering educational tools are critical to maximizing the potential of RE. Used wisely, electronic communication technologies can improve the human physical condition and the environment, while also preserving or even enhancing the human spirit.

Renewable energy

Renewable sources of energy constitute a cornerstone of any environmentally- and economically-sustainable global future. Access to clean, affordable, and reliable energy – including that derived from solar photovoltaic, solar thermal, wind, geothermal, bioenergy, and small-scale hydropower systems – can improve the quality of human life in villages and cities, and benefit local and global ecosystems.

Renewable energy systems can:

- contribute to a more flexible and reliable energy system through distributed diversity;
- reduce urban air pollution and its associated adverse health impacts;
- reduce serious threats to the global atmosphere, oceans, and terrestrial ecosystems;
- contribute to economic stability and national security by decreasing reliance on fuel imports;
- preserve natural resources; and
- use local resources and create local jobs.

Renewable energy is especially critical to improving the quality of life in rural villages. As described succinctly by José Goldemberg and Thomas B Johansson (1995):

> *A better life and an improved standard of living are the fundamental aspirations of the 70 per cent of humanity living in the poor countries of Africa, Latin America, Middle East, and South-east Asia, and socio-economic development is a means to achieve it. It is estimated that worldwide 2 billion people live below the poverty line. This situation is fertile ground for political unrest. Hopelessness and despair also lead people to emigrate to the industrialized countries in search of a better future. For the poor, a better life first means satisfying the basic human needs, including access to jobs, food, health services, education, housing, running water, sewage, etc. In providing for these needs, energy is an important element.*

In villages, renewable energy can:

- reduce disease by purifying food and water, sterilizing medical equipment, and refrigerating vaccines;
- improve education by powering electric lights and communication devices;

- decrease serious health problems and reduce fire risks by eliminating indoor combustion sources such as wood fires and kerosene lamps;[1]
- reduce the enormous amount of time spent by millions of women and children gathering and transporting water and firewood;
- power agricultural operations (increasing food supply) and micro-industries (creating jobs and income);
- improve food quality, nutrition, and availability through better cooking techniques; and (Batliwala 1995)
- enhance social justice.[2]

Recent advances and continued long-term trends justify optimistic thinking about renewable energy. For instance, in India, the government has estimated that there is a long-term potential to obtain 50 000 MW of power from renewable sources; there are currently plans to install 3000 MW of new solar and wind grid-based power between 1999 and 2002 (US Department of Commerce 1998). The solar photovoltaic energy sector in India is presently growing at 28 per cent annually, and wind power at 22 per cent (US Department of Commerce 1998).

But if the full potential of renewables is to be realized, in India or elsewhere, it must be acknowledged that technical and economic feasibility do not comprise a sufficient condition for the transition to renewable sources of energy. Education, considered in a very broad sense, is also critical to success.

Renewable energy education

The adoption of a renewable energy system – which often involves the displacement of another source of energy (or some method of accomplishing a task) – encompasses many steps. Figure 1 is one example of how the process can evolve, from first becoming aware of the new renewable energy technology, to acquiring it, installing it, and evaluating its performance in order to inform subsequent energy decisions.[3]

---

[1] The health impacts of gathering and burning fuelwood include, among other maladies, respiratory illnesses, insect and reptile bites, skin infections, carbon monoxide and smoke poisoning, burns, cataracts, reduced child care, allergic reactions, fungal infections, fatigue, arthritis, reproductive pathologies, lung cancer, and chronic bronchitis. (Batliwala 1995)

[2] 'Energy plays a key role in achieving these [social justice] goals. Lack of fulfilment of basic needs (for food, water, fuel, shelter, health, and education) perpetuates the poor's – especially poor women's – social, economic, and political disadvantage and powerlessness. Nations must invest in improved energy systems to achieve social justice as well as economic growth.' (Batliwala 1995)

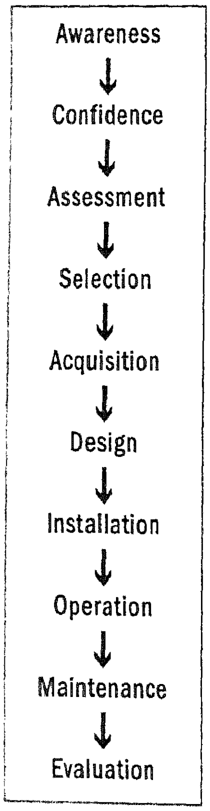


Figure 1 Steps in the adoption of a renewable energy system

Quite often, different people are responsible for each step of the process, especially in companies and government agencies where there is strict division of labour. If you consider the broad social, political, and economic framework in which energy systems evolve, you become aware of an incredible spectrum of people who participate in some way in the adoption of renewable energy systems. The gamut of participants includes consumers, manufacturers, distributors, system installers, legislators, technicians, financiers, investors, municipal planners, voters, educators, students, procurement officials, builders, architects, advocates, retailers, utility

---

ould easily create similar diagrams to illustrate this process which involve more or fewer what is important is that all steps in the process are accounted for somewhere. Since a key e of diagrams like this is to assist in planning an educational approach (whch is not sed concretely in this paper), the optimum 'step size' is that which allows a specific tional goal to be attributed wholly to one responsible party.

regulators, lawyers, media, scientists, corporate managers, economists, and insurance agents.

The important point to consider here is that one weak link in the educational system – resulting in a lack of confidence in the technology, or faulty system design, or inadequate maintenance, or insufficient promotion – or legal barriers can jeopardize the entire process. Each step concerns different people with different educational needs, and they must all be considered by renewable energy educators.

Electronic communication technologies

Electronic communication technologies, such as the Internet and multimedia software, have important roles to play in educating the whole range of people described above. They have unique characteristics that make them especially effective in addressing global economic and environmental concerns that inherently transcend political and cultural borders. Depending on the specific communication technology, these attributes include,

- high information **storage capacity** and density (for instance, a 25-gram optical disc can store hundreds of megabytes of data, equal to several large volumes of printed text);
- nearly **instantaneous data transmission** via networks, even to remote locations via satellite,
- **multimedia** presentation of information, which is more engaging and which has been proven to be more effective than conventional education and training techniques (Fletcher 1990);
- **interactivity**, allowing a more personal and effective educational experience, especially in children;
- **interconnectivity**, allowing information resources to be shared and integrated, permitting long-distance group discussion and team collaboration; and
- capability to perform **complex calculations**, allowing scientific modeling, data visualization, complex systems analysis, economic forecasting, and rapid technical system design.

Electronic communication tools can lead to rich educational experiences that are qualitatively different from conventional modes of communicating. They can engage, empower, and connect in a way that printed materials and other traditional media cannot. Both electronic and conventional communication tools are important, of course, but the digital tools offer exciting new opportunities that we are just beginning to capitalize on.

Examples of educational resources

There are many electronic renewable energy educational resources today that address the needs of a diverse audience. Here are a few examples; there are also several sites on the Internet[4] where additional resources are listed. (*See Annexure 1 for a list of relevant Internet sites*)

Renewing India

This web site[5], sponsored by Winrock International and the US Agency for International Development, combines extensive background material on renewable energy in India with an interactive discussion forum for decision-makers, advocates, companies, and investors. This kind of interaction is possible only with global communication networks, and represents an entirely new way of conducting education and business. The site (Figure 2) has attracted a worldwide audience interested in all aspects of renewables in India, and is constantly updated with new information. By focusing specifically on one geographical market for renewables, the site has become a valuable commercial catalyst in addition to providing general education.

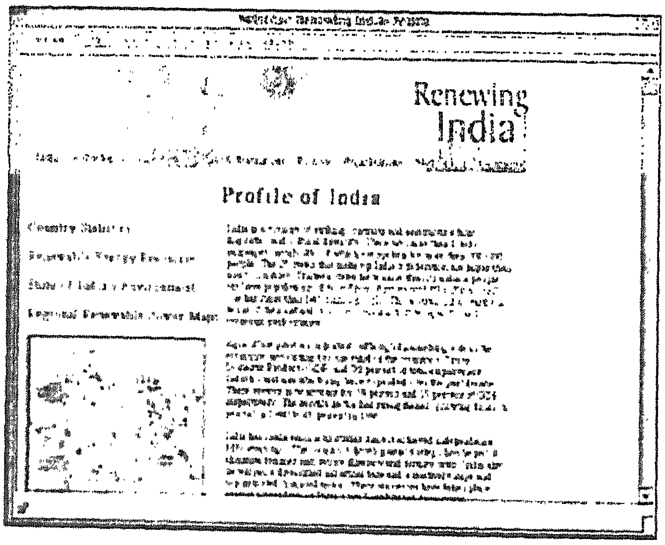


Figure 2 Renewing India web site

SolarSizer

This software program[6] (Figure 3) integrates a professional PV (photovoltaic) sizing tool and educational materials on

---

[4] Such as CREST's list of sustainable energy software (http://solstice.crest.org/software-central/html/other-software.shtml), the Global Energy marketplace (http://gem.crest.org/), and the US Department of Energy's Energy Efficiency and Renewable energy Network (http://www.eren.doe.gov).

[5] Renewing India is on the Internet at http://www.renewingindia.org/. It was produced by REPSO India, Winrock International, the US Agency for International Development, and CREST.

[6] More information on SolarSizer is available at http://www.crest.org/software-central/. It was produced by Solar Energy International and CREST, and was funded by the US Department of Energy

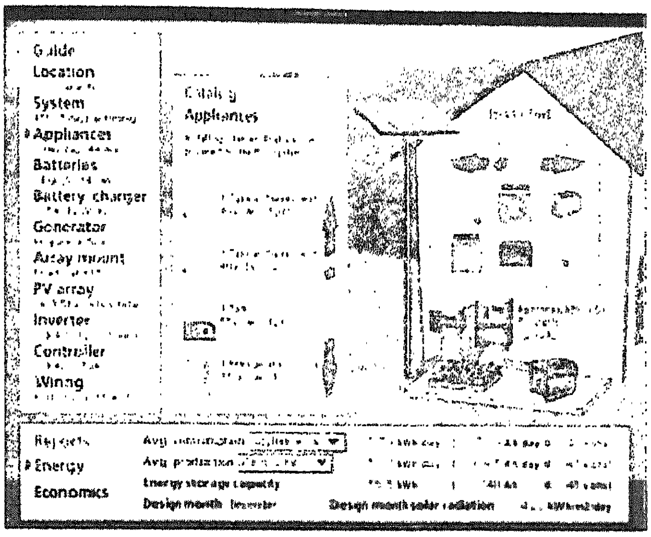


Figure 3 SolarSizer program

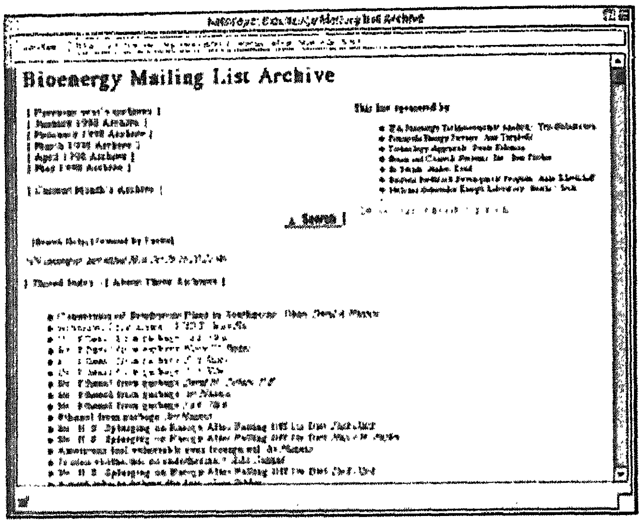
small-scale PV systems. The educational component of the software ensures that the system designer achieves the optimal configuration; the program has background material on PV system design and also warns the user if any components in the system are incompatible (for instance, a 24-volt inverter being used with 12-volt appliances). Tools like SolarSizer also allow basic system design to be performed by non-engineers, which is especially useful in evaluating the feasibility of renewable energy at the early stages of adoption. The program is a key component of Internet-based distance learning PV courses offered by Solar Energy International (Colorado, USA), greatly increasing the number of people around the world who are trained to design and install small-scale PV systems.

Bioenergy

This electronic discussion group[7] on the Internet (Figure 4) is a lively and productive meeting place where ideas are exchanged, opportunities are announced, technical questions are answered, and partnerships are explored. Before electronic networks, such exchanges were virtually impossible. Now, experts, consumers, technicians, students, government representatives, and entrepreneurs can interact and learn from each other. Dozens of e-mail messages from around the world each day – thousands per year – demonstrate the popularity of this and other renewable energy discussion forums. In fact, the original Bioenergy discussion group had to be split into more specific

---

[7] For more information about the Bioenergy and other renewable energy discussion groups, see http://www.crest.org/discuss.shtml



Bioenergy Mailing List Archive

Figure 4 Bioenergy electronic discussion group

groups because the volume of communication was so high. All e-mail messages are archived and searchable on the Internet, providing a unique resource on a range of bioenergy topics. Other renewable energy discussion groups are also available on photovoltaics, electric vehicles, green electricity, green energy finance, and sustainable power for remote villages through NREL's (National Renewable Energy Laboratory) important RSVP (Remote Sustainable Village Power) program.

Real Goods Several commercial Internet resources, such as the very successful web site (Figure 5) of Real Goods, Inc.[8] in

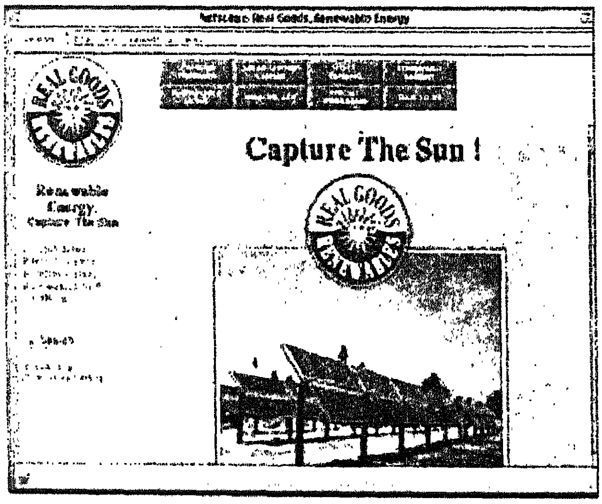


Figure 5 Real Goods web site

---

[8] The Real Goods web site is accessible at http://www.realgoods.com/

California, U S A, integrate educational materials with commerce, teaching their audience while also selling their renewable energy products. Real Goods sells hundreds of renewable energy and sustainable living products each month, totalling on the order of US $100 000 in annual sales through the Internet (and probably resulting in higher non-Internet sales through improved awareness of the company). An important benefit to the educational materials being integrated with the commercial component of the site is that customers can get questions answered themselves instead of burdening the Real Goods technical staff, thus reducing costs.

Danish Wind Turbine Manufacturers Association

This web site[9] is simply one of the best renewable energy resources on the Internet. It includes more than 100 multimedia pages on wind and the environment, frequently-asked-questions about wind energy, the full text of several publications, wind energy Internet links, downloadable presentation graphics, a web-based wind energy economics calculator (Figure 6), and an interactive quiz. The site includes a number of user-friendly features such as text in several languages, instructions for configuring your web browser to effectively view the site, and the capability to download the entire web site to your personal computer and view it locally instead of over the network. The screen shot above illustrates the economics calculator, which is powerful but easy to use. This web site does an incredible job of integrating educational materials with technical and promotional material about the technology. It is truly a model for other renewable energy trade associations.

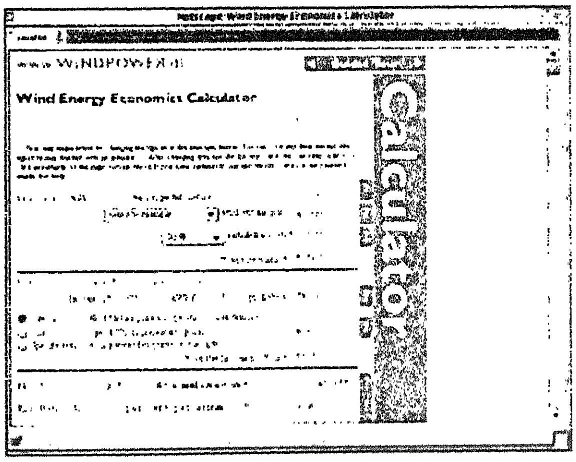


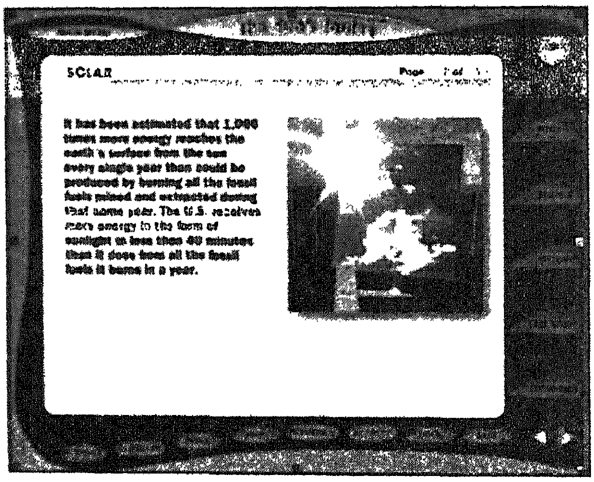
Figure 6 The web-based wind energy economics calculator

---

[9] The Danish Wind Turbine Manufacturers Association web site is accessible at http://www.windpower.dk/

The Sun's Joules

RE educational CD-ROMs for children, such as The Sun's Joules[10] (Figure 7), captivate the younger generation and introduce them to the possibilities of a sustainable future. Interactivity in the programs allows kids to learn by *doing* instead of just reading; the active learning that results is more effective than the relatively passive education provided by books and lectures. Making education interesting is the first step in making education effective, and interactive multimedia has a lot to contribute to innovative instruction.



It has been estimated that 1,000 times more energy reaches the earth's surface from the sun every single year than could be produced by burning all the fossil fuels mined and extracted during that same year. The U.S. receives more energy in the form of sunlight in less than 40 minutes than it does from all the fossil fuels it burns in a year.

Figure 7 The Sun's Joules: an educational CD-ROM

Sustainable Energy

This web site[11] of the UNDP Sustainable Energy and Environment Division web site is an excellent example of on-line publication of critical policy documents. The site has the full text of several large reports on-line, well organized and easy to use. For example, the site contains the entirety of both *Energy After Rio: Prospects and challenges* by A K N Reddy, R H Williams, and T B Johansson, and *Energy as an instrument for socio-economic policy* by J Goldemberg and T B Johansson (Figure 8). These important reports reach a much wider audience through electronic publication than they otherwise would through the distribution of printed documents (and of course the economic and environmental savings of digital document distribution are considerable).

---

[10] More information on The Sun's Joules is available at http:\\www.crest.org/software-central/. It was produced by CREST, and sponsored by the US Department of Energy and the US National Renewable Energy Laboratory.

[11] The UNDP SEED Sustainable Energy web site, located within its Energy and Atmosphere Programme, is at http://www.undp.org/seed/eap/susenergy/index.html

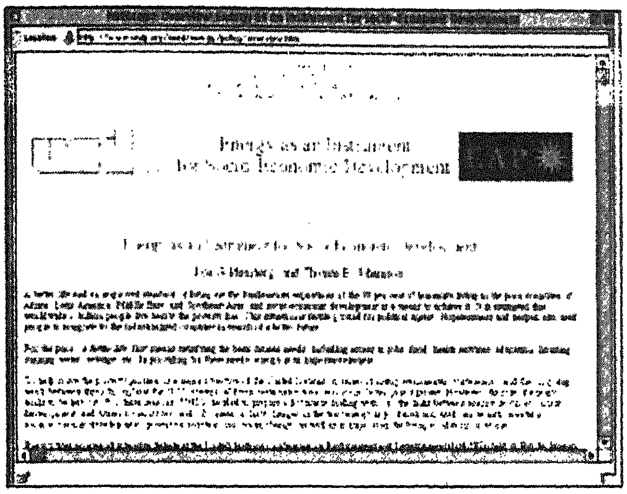


Figure 8 Sustainable Energy web site

Renewable Energy in Latin America and the Caribbean

The RELAC (Renewable Energy in Latin America and the Caribbean) CD-ROM[12] (Figure 9) is a successful educational tool because of its focus on one region of the world, allowing the technologies, applications, case studies, and discussions about economics to be very specific. RELAC incorporates Latin American design motifs in its interface, and the text is in both English and Spanish. Multilingual communication and education are facilitated by electronic communication technologies, and new tools are under development to translate digital communication in real time, improving the capability of people in different countries to collaborate.

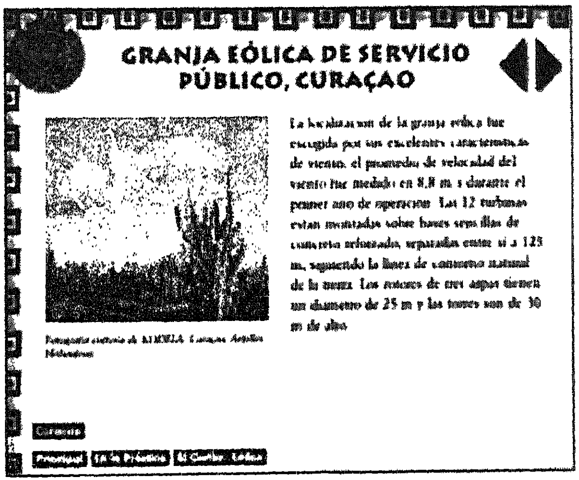


Figure 9 RELAC CD-ROM

---

[12] More information on RELAC is available at http://www.crest.org/software-central/. It was produced by CREST and Solar Energy International, and was sponsored by the US Agency for International Development and Winrock International

Energy Quest

This web site (Figure 10) of California (USA) Energy Commission for children is an excellent example of tailoring an educational Internet tool to a younger audience[13]. It is fun, exciting, surprising, active, and colourful, and is therefore able to captivate kids long enough to introduce them to renewable energy and energy efficiency. The site is an excellent example of understanding the audience and creating an educational resource that will work for them.

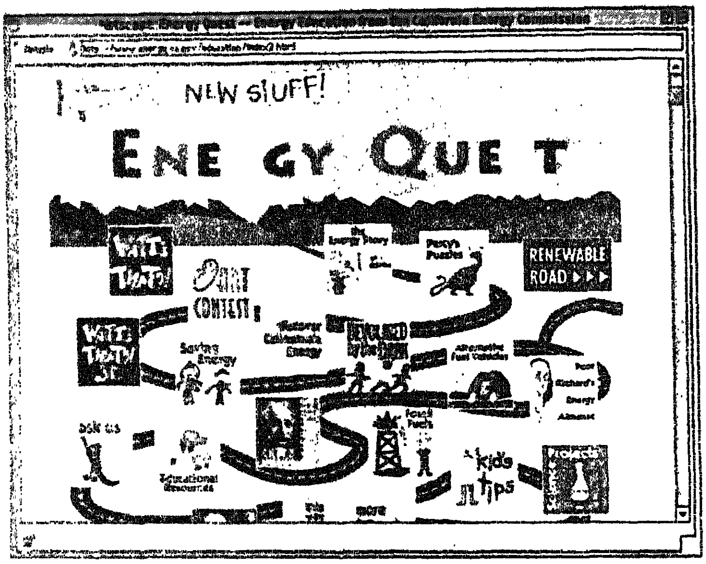


Figure 10 Energy Quest

Community PV

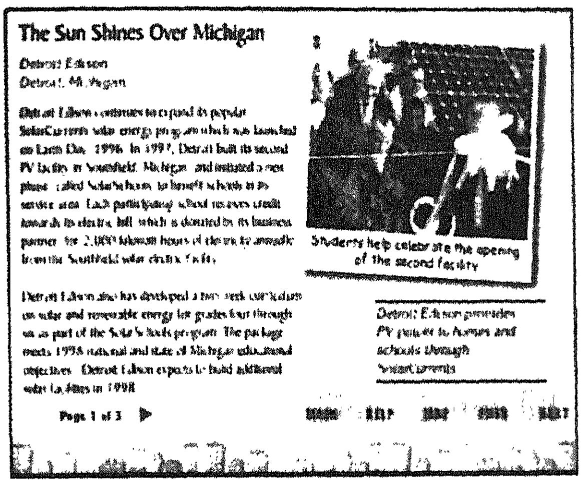
This CD-ROM[14] has as its audience people who are interested in making PV projects happen in their communities. It has an introduction to PV technology, dozens of success stories of PV projects, and a unique *solar town meeting* where different community members share their perspectives and ideas about PV (Figure 11). The multimedia nature of the software helps make photovoltaics exciting, which is important in a promotion/advocacy tool.

These pioneering educational resources, which are of course just the beginning, are absolutely critical to maximizing the potential of renewable energy. In many cases, technologies that are technically and economically sound are not adopted because someone along the long road to change was simply under-informed. The tools described above variously

---

[13] The Energy Quest web site is accessible at http://www.energy.ca.gov/education/index2.html

[14] More information on the Community PV CD-ROM is available at http://www.crest.org/software-central . It was produced by the UPVG (Utility Photo Voltaic Group) and CREST, and was sponsored by the US Department of Energy, UPVG, and UPVG member utilities.



The Sun Shines Over Michigan

Detroit Edison
Detroit, Michigan

Students help celebrate the opening of the second facility

Page 1 of 3

Figure 11 Community PV CD-ROM

target consumers, decision-makers, community members, children, entrepreneurs, engineers, educators, and others. Only by making renewable energy educational materials available to everyone in the chain of technological change can we maximize the potential of renewable energy to contribute to a positive future.

Conclusion

Let us not lose sight of the fact that behind high-tech and flashy communication technologies, tools, and networks are *people*. Renewable energy education can achieve its goals of informing a diverse audience about sustainable energy while never forgetting that people write computer software, people run computer programs, people use the Internet, and people will always be the agents and beneficiaries of change, technological or otherwise: Information systems need not be devoid of community, of culture, of art, of spirituality; in fact, incorporating cultural elements into educational tools can enhance their effectiveness.

This means paying special attention to the needs and customs of the people you are trying to teach. It means considering renewable energy in a full social and cultural context, not as an isolated technological system. It means going beyond facts and statistics and calculations and recognizing that art and design and poetry and music all have important roles to play in education at all levels.

Used wisely, electronic communication technologies can improve the human physical condition and the environment, while also preserving or even enhancing the human spirit. It is our challenge to develop effective educational tools that are informed by the context of the societies in which we hope they may flourish.

References

Batliwala S. 1995
In *Energy as an instrument social-economic development* (Online), edited by Goldernberg J, Johansson T B
Available at: http://www.undp.org/seed/energy/policy/index.html

Fletcher J. 1990
Effectiveness and cost of interactive video disc instruction in defense training and education
Washington, DC: Institute for Defense Analysis.

Goldenberg J, Johansson TB (eds). 1995
Energy as an instrument social-economic development (Online)
Available at: http://www.undp.org/seed/energy/policy/index.html

US Department of Commerce. 1998
Industry Sector Analysis: India–Alternate Energy–Solar and Wind (online)
Available at: http://strategis.ic.gc.ca/ssg/ea01543e.html

Annexure 1

Internet sites on renewable energy education

1. *http://www.crest.org/staff/ceg/isree-links.html*
2. California Energy Commission, Energy Quest
   http://www.energy.ca.gov/education/index2.html
3. Center for Renewable Energy and Sustainable Technology
   http://www.crest.org/
4. CREST software central
   http://www.crest.org/software-central
5. CREST renewable energy discussion groups
   http://www.crest.org/discuss.shtml
6. Danish Wind Turbine Manufacturers Association
   http://www.windpower.dk
7. Global Energy Marketplace
   http://gem.crest.org
8. Real Goods, Inc.
   http://www.realgoods.com
9. Renewing India
   http://www.renewingindia.org
10. Solar Energy International
    http://www.solarenergy.org/index.html
11. United Nations Development Programme, sustainable energy resources
    http://www.undp.org/seed/eap/susenergy/index.html
12. US Agency for International Development
    http://gaia.usaid.gov/
13. US Department of Commerce, India renewable energy analysis
    http://strategis.ic.gc.ca/SSG/ea01543e.html
14. US Department of Energy, Energy Efficiency and Renewable Energy Network
    http://www.eren.doe.gov/
15. US Department of Energy, Energy Efficiency and Renewable Energy Network building tools directory
    http://www.eren.doe.gov/buildings/tools_directory/
16. U S Energy Information Agency, Renewable Energy Annual international chapter
    http://www.eia.doe.gov/cneaf/solar.renewables/renewable.energy.annual/chap12.html
17. US National Renewable Energy Laboratory
    http://www.nrel.gov
18. US NREL Remote Sustainable Village Power
    http://rsvp.nrel.gov/
19. Utility Photovoltaic Group
    http://www.upvg.org/upvg/index.htm
20. Winrock International
    http://www.winrock.org
21. Winrock/USAID Renewable Energy Project Support Offices
    http://www.crest.org/clients/repso

Department of
Physics,
Thiagarajar
College of
Engineering,
Madurai - 625 015
India

D Mutharasu*, C E Sooriamoorthi

Education television as a medium for renewable energy technology propagation

Renewable energy education: current scenario and future projections
pp. 246-249

Abstract

Television, being a powerful audio-visual medium, can be effectively used for popularizing and disseminating renewable and solar energy technologies to the masses as well as to aspiring solar energy technicians. The content of the television programme can be divided into three categories: 1) artistic presentation, 2) simple do-it-yourself instructions, and 3) technician information suitable for commercial solar device installations. The artistic presentation could consist of puppet shows, street plays, and cartoons depicting the importance and usefulness of RE (renewable energy). After watching the do-it-yourself instruction programmes, viewers may be able to collect and fabricate devices like cardboard solar cookers, solar stills, and other simple RE devices. The technician programme will provide all the necessary information and instructions to educate an average technician in the installation and running of devices like solar flat-plate collectors, solar photovoltaic electrical systems, parabolic concentrators for mass cooking, simple biogas plants, and other RE devices.

The authors have prepared such programmes using the services of the EMRC (Educational Media Research Centre) of the Madurai Kamaraj University, Madurai, Tamil Nadu. These programmes were screened on television during the educational programmes of the University Grants Commission. This paper presents the details of the preparation of such programmes and the response from the viewers consisting of students and the general public. The University libraries and public libraries can play an impressive role in the propagation of RETs (renewable energy technologies) as they have facilities for screening the video films. Through audio and video presentations, the television programme will effectively convey RE awareness to the students and the general public.

---

* Author for correspondence

Introduction

In a developing country like India, the rapid depletion of hydrocarbon fuels necessitates that the common masses be effectively educated in the utilization of REs like solar, wind, biomass, and biogas. Although these technologies are simple and cost-effective, an educational medium is necessary to popularize their use. The advanced development in these areas could be left to higher research institutions, but what can be effectively transferred to the common masses can be done with the help of media like television. In India, where more than 70% of the population watches television, it is essential to produce television programmes to convey information about RETs simply and effectively.

The Madurai Kamaraj University has been chosen as one of the EMRC by the UGC (University Grants Commission). The EMRC has all infrastructural facilities to prepare educational television programmes. The University also has a department exclusively devoted to the development of solar energy research. The Department of Solar Energy, Madurai Kamaraj University and the EMRC jointly planned and prepared three educational media programmes, namely:

- clean energy technologies,
- solar drying of tea leaves, and
- solar cooking.

Clean energy technologies

The programme on clean energy technologies covers both solar and wind energy. Solar energy utilization is further divided into solar thermal energy conversion and solar photovoltaic conversion.

The film begins with showing the start of a conventional fire and then points out the disadvantages of the heat from the firewood. Then the viewers are informed that in the tropical countries, sunlight – solar energy – is abundantly available at no cost. The basic principle of the greenhouse effect is explained next to emphasize the conversion of sunlight into heat. The solar thermal route as applied in solar cookers and flat plate collectors is also explained. Elaboration of the fabrication technology of these equipments is avoided. The viewers can see the method of using solar cookers as well as flat-plate collectors. A step-by-step instruction leads the viewer to get the necessary education for using these devices. The viewers are explained the method of mounting the flat plate collectors and the direction of inclination needed for the collector to get sufficient sunlight.

All these devices need constant servicing such as cleaning the glass plate everyday, cleaning the mirror, and looking for any water leakage. Since seeing is believing, the entire process of solar cooking is also demonstrated.

For the PV (photovoltaic) system, the solar cells are shown as effective devices to make electricity from sunlight. The PV principles are not necessary here. The PV array is shown for energizing agricultural water pumps. Using a line drawing, the mounting and working of a solar pump are explained. It is also explained why the array should be facing south and rotated about a south-north axis slowly to follow the sun. Generally, the solar arrays have three positions to catch good sunlight in the morning and evening. The programme explains how the cells can be mounted and operated.

Solar drying of tea leaves

Making tea leaves is an art as well as a science. After crushing and oxidation, the tea leaves are properly dried at 140 °C to seal the flavour of the tea. In the conventional tea factories, hot air at 140 °C is prepared by burning firewood or passing high speed oil over a bed of tea leaves undergoing oxidation. The CTC (curl, twist and cut method) and orthodox type tea are prepared in India. Tea factories spend millions of rupees for firewood/diesel oil. A technique has now been developed to pre-heat air using solar energy absorbed by the tinned roof of tea factories. The hot air from the roof is in the ranges of 50 °C to 70 °C depending upon the solar insolation conditions. The solar preheated air is sent into the conventional furnace to heat it further to 140 °C. Since the preheated air takes less fuel, fuel saving is enormous and the cost of installation of solar roof hot air system can be recovered within a few years. This programme is intended for tea factory managers and owners. So, the level of presentation is kept at such a level that people with technical background will be able to absorb the technique for their own benefit. Still, the common masses can also understand 70 per cent of the presentation This programme runs for 30 minutes.

Solar cooking

This programme is intended for housewives in small towns and villages. The programme commences with a basic description of a standard solar cooker. Its various parts are identified. The method of cooking, the amount of cooking, and the time needed for cooking are explained. The programme demonstrates step by step how the cooker is charged with rice, *dal* (pulses), and vegetables in respective cooking vessels. The precautions like cooking in the closed vessels and cleaning of the glass plate and mirror are pointed out. The cooking procedure is described in a simple language. Viewers are informed which food items may be cooked in solar cookers and which items are not suited for the same. The duration of the programme is 30 minutes.

The EMRC has edited, titled, and timed the video programmes. A team of cameramen, sound recorders, coordinators, and solar scientists spent about five days for each programme. The contents of the programmes were planned precisely with respect to the site of shooting.

These programmes were initially screened for high school students, college students, and common masses to elicit their response. The high school students could easily follow the solar cooking as well as tea drying programmes. The common people were interested only in the solar cooking programme. The students of technical institutions evinced keen interest in the programme on solar photovoltaic technology. Subsequently, the above two programmes (clean energy technology and solar tea drying) were screened at the national UGC television educational programme. These programmes were shown repeatedly on different days and at different times.

The Department of Solar Energy received a lot of correspondence from various sections of the viewers. Most of the young viewers were interested in the manufacture and sale of solar devices. Their responses clearly show the entrepreneurial aspect of solar technology; it can help create employment avenues. A few responses were for purchasing solar cookers. Since solar tea drying is already catching up among tea growers due to the conduction of various workshops, there was not much response for it.

Conclusion

Since India is a country with very low literacy rate, such video programmes could play an effective role in propagating the emerging RETs. The programmes could be prepared in a way that the village artisan can fabricate the devices and service them. Our experience shows that the television education broadcasting medium is very effective in educating viewers and creating an awareness for RETs.

University of
Ljubljana,
Faculty of
Mechanical
Engineering,
Aškerčeva 6
SI-1000 Ljubljana
Slovenia

Saso Medved*, Suzana Domjan, Peter Novak

Teaching aids for lectures on renewable energy sources - an example from Slovenia

Renewable energy education: current scenario and future projections
pp. 250-261

Abstract

Slovenia's large energy dependence on imported fossil fuels and the obligation to reduce CO_2 emissions that it adopted in the Kyoto agreement are the reasons why Slovenia has been striving for a number of years to save energy and implement renewable energy sources. Renewable energy sources are defined as the most strategically important energy sources. The introduction of renewable energy sources is encouraged through public competition, subsidies, and education. Education is also carried out at the university level, at the Faculty of Mechanical Engineering, in Ljubljana. Lectures on renewable energy sources have already been part of the curriculum for 10 years. Theoretical and practical exercises especially have been an important part of these lectures. To further improve the learning process, numerous teaching aids were prepared following the principle 'students for students'. All equipment presented in this paper has been prepared with the help of students as part of their graduation thesis and seminars. Educational aids are divided into three main groups – Eemultimedia; Solar Professor; Solar Engineer and Solar Calendar, all of which are presented in this paper.

About Slovenia

The Republic of Slovenia is a democratic republic. It has a population of 1 975 000 and a surface area of 20 256 km^2. Its capital is Ljubljana. Slovenia's geographical centre is at 46°07' N latitude and 14°49' E longitude. Aerial distances by geographical latitude and longitude are 1°28' and 3°13'. Slovenia lies in south-east Central Europe and borders on Austria, Italy, Hungary, and Croatia. The Alps, the Dinaric mountain range, and the Pannonian plain cover the Slovenian territory.

Energy supply of Slovenia

Slovenia has few of its own energy sources, and has to import over 70% of its energy. The primary annual consumption of energy in recent years has been about 250 PJ. The most important energy sources include fossil fuels (68%), nuclear (17%), and water energy and biomass (15%). Table 1 gives a comparison of the energy and ecology indicators for Slovenia and the European Union.

Table 1 Some energy and ecology indicators for Slovenia in comparison with the European Union

Indicators	Slovenia	EU
Energy import dependency(%)	70	51
Energy transformation efficiency (final/primary) (%)	62	64
Final energy demand per capita (GJ/capita)	81	90
Final energy demand per GMP (MJ/ECU)	25.5	13
CO_2 emissions per capita (tonnes/capita)	7.1	8.7
SO_2 emissions per capita (kg/capita)	60	30

Slovenia has two universities. The older one is in Ljubljana and was founded in 1919. However, the development of study of technical science on Slovenian territory began in 1767 with lectures in mechanics at first degree study institutions which followed the founding of the Gymnasium in 1563, in Ljubljana. In 1938, a project for the construction of an Institute of Mechanical Engineering was approved by the state. The central building of the Faculty of Mechanical Engineering was completed by the beginning of World War II and the opening ceremony took place on 15 March 1946. Due to an increase in the number of students and the need for new laboratories, a new building was constructed in 1972.

In the last decade, an average of 1250 students per year have attended the Faculty of Mechanical Engineering in Ljubljana.

Renewable energy sources in Slovenia

Slovenia's large energy dependence on imported energy sources and the adopted obligation to reduce CO_2 emissions, have dictated an orientation towards efficient energy use and greater introduction of RE sources. The most important of these include solar, hydro, biomass, and geothermal energy. The basic characteristics of the use of RE sources in Slovenia are given in Table 2.

Table 2 RE sources in Slovenia - current status

Solar radiation	1000-1400 kWh/m^2/a
Solar thermal	low and middle temperature, 120 000 m^2 of solar collectors are installed
Solar photovoltaic	100% electricity production in natural parks, stand-alone systems, >110 kWp
Hydro power	500 small and micro hydro power plants, 10% of annual electricity production
Biomass	The landscape is heavily forested (54% of surface area is covered with forests), presently, biomass provides 9% of final energy
Geothermal	Important potential in north-east Slovenia, 70 boreholes, thermal power 130 MW
Wind	weak potential, only few turbines < 10kW

The introduction of RE sources is encouraged through public competition, subsidies, and education. Education is also carried out at the university level, at the Faculty of Mechanical Engineering, University of Ljubljana.

Renewable energy sources curriculums

The faculty currently provides a two-and-a-half year college programme, a four-year undergraduate programme, and a two-year graduate programme. In addition, there are also several specialized courses. Among others, lectures on RE sources have been an ongoing feature since the 1988/89 school-year in both junior college and undergraduate programmes (Figure 1). This programme was originated by Prof. Peter Novak. To improve the learning process, several teaching aids were prepared by the staff and students. The educational aids are divided into three groups - Eemultimedia, Solar Professor, and Solar Engineer. Figure 2 shows the number of theses on RE sources for courses on graduate, postgraduate, diploma, and research.

Eemultimedia

The computer application Eemultimedia presents RE sources, their energy and ecological values, and their role in the rational use of energy together with technologies and practical

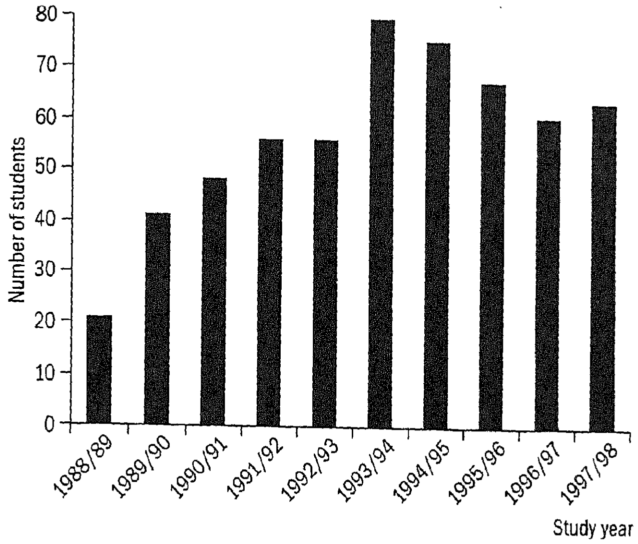


Figure 1 Number of students per study year within RE sources curriculums since the beginning of the programme

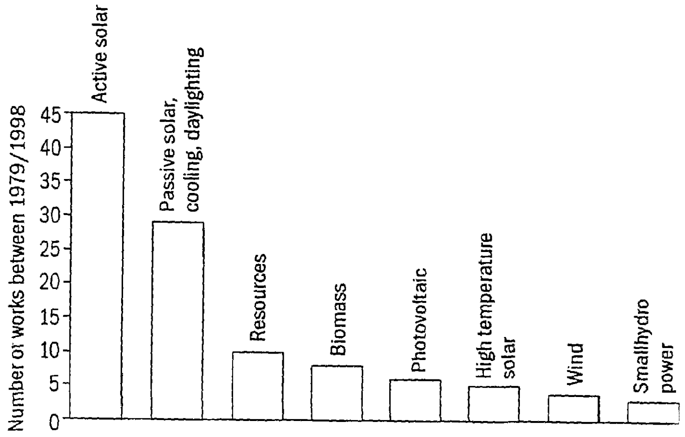


Figure 2 Theses on RE sources (with Prof. Peter Novak as mentor)

examples both in Slovenia and the world over. It is designed as an interactive multimedia software package with text, pictures, drawings, animation, and sound effects. It contains 620 scenes with more than 440 colour pictures, 260 drawings, charts, maps, and 170 animated scenes. Published in CD-ROM format in 1995, it was in fact the first Slovenian educational CD-ROM as well as the first multimedia educational tool in Slovenian language. Eemultimedia also contains the first complete overview of the role and potential of RE sources in Slovenia.

The CD-ROM package is divided into 12 chapters beginning with a general chapter describing the problems of energy supply and the ecology of humanity (Figure 3). Individual chapters describe the theme using the same pattern (which are listed below).

- Physical basis
- Theoretical and technical potential (Figure 4)
- Technologies and principles of exploitation (Figures 5 and 6)
- Experiences and examples in Slovenia and the world
- Ecology: advantages and disadvantages

Students' working procedure with Eemultimedia: since the number of students who own a computer has increased greatly (>90%), they can now borrow a CD-ROM at the beginning of the semester and use it for individual study at home.

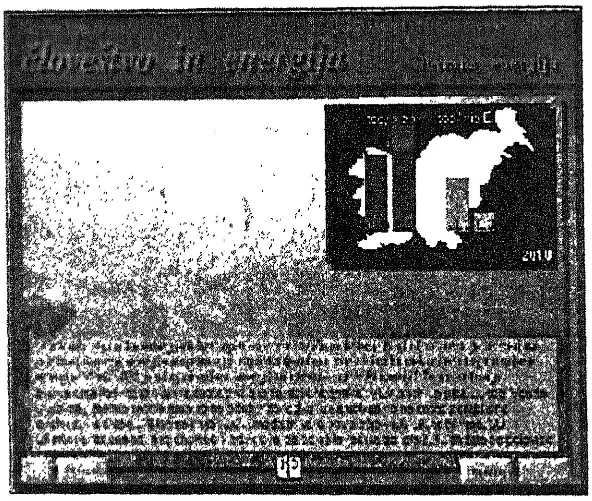


Figure 3 Some examples of the scenes in Eemultimedia; presentation of ecological problems

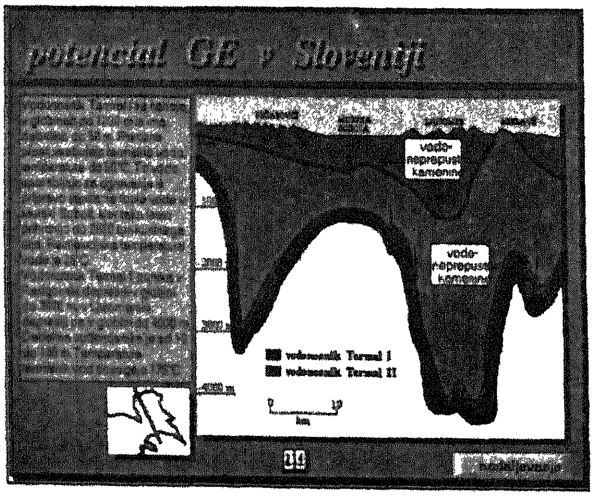


Figure 4 Geothermal potential in Slovenia

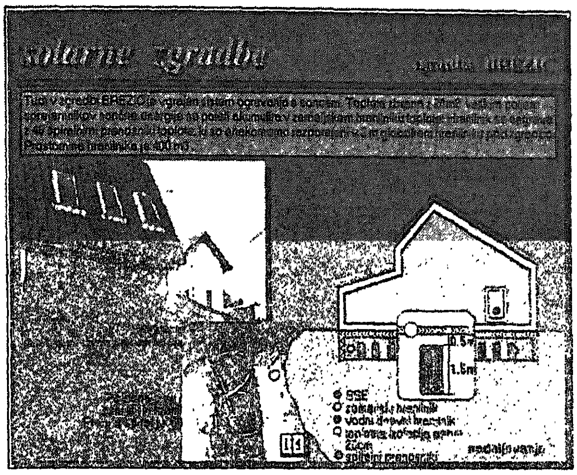


Figure 5 Description of an active solar heated house

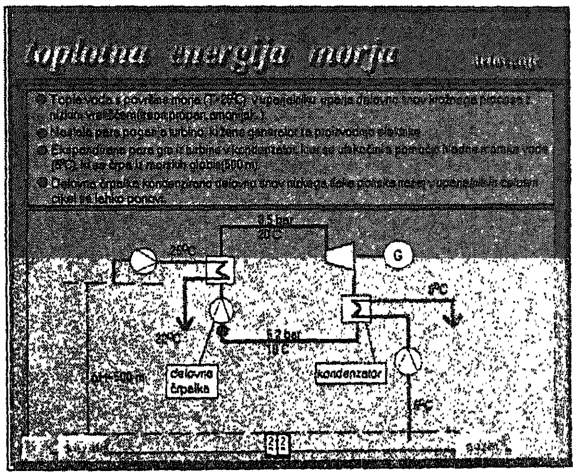


Figure 6 Animated presentation of an ocean thermal power plant in operation

Solar Professor

Like the well-known software codes such as Trnsys, Microlumen, Phoenics, and Fidap, a set of programs named Solar Professor has been developed with the help of students. Solar Professor is a user-friendly software package which includes codes for solar radiation calculation and shading studies ($\text{SHADE}^{\text{cad}}$) and active solar systems (SUN^{cad}), passive solar systems and building energy consumption analyses ($\text{E}^{+\text{cad}}$) as well as PV system analyses and planning (PV^{cad}). The codes are written in Visual Basic and are based on f-chart and M5000 methods, among others.

Figures 7 to 16 show the students working procedure with Solar Professor: work is conducted in the computer lab; after the presentation of mathematical bases, work is presented on large screen using the available software and viewed by all students. The students then create individual projects for actual buildings.

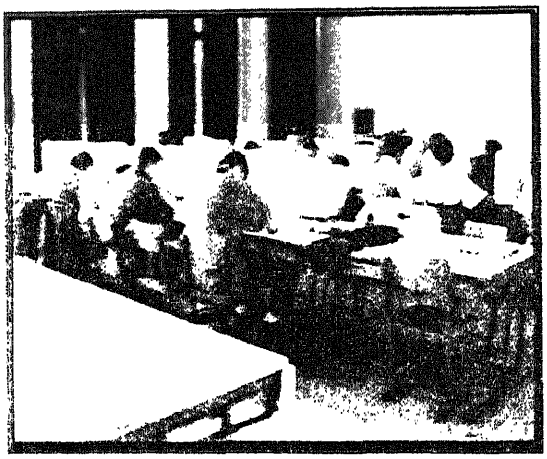
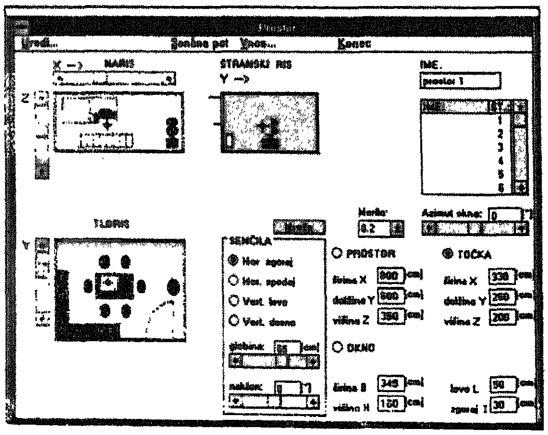


Figure 7 Students in a CAD classroom



IME. prostor 1

Merilo: 0.2

Azimut okna: 0 [°]

širina X 800 [cm]

dolžina Y 800 [cm]

višina Z 350 [cm]

širina X 330 [cm]

dolžina Y 260 [cm]

višina Z 200 [cm]

globina: 85 [cm]

naklon: 0 [°]

širina B 345 [cm]

višina H 180 [cm]

levo L 50 [cm]

zgoraj T 30 [cm]

Figure 8 SHADE^{cad} basic input window showing description of the room's interior and window size and position, position and type of shading devices, and the position of an observed point inside the room

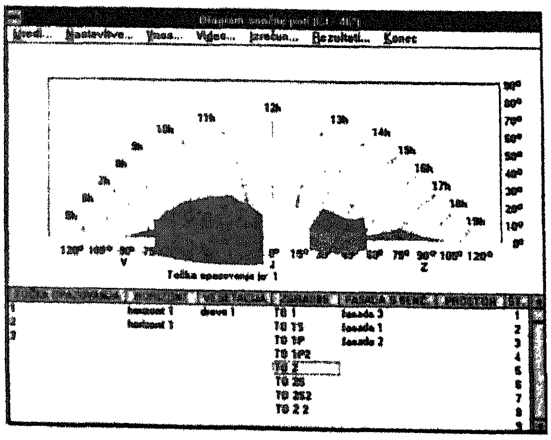
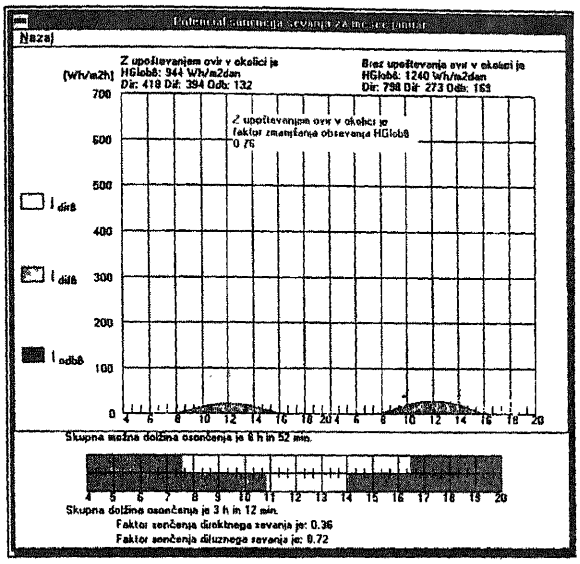


Figure 9 Input window for sun trace and shading calculations showing different horizons, trees, neighbouring buildings, and facade obstructions



Z upoštevanjem ovir v okolici je
HGlobß: 944 Wh/m2dan
Dir: 418 Dif: 394 Odb: 132

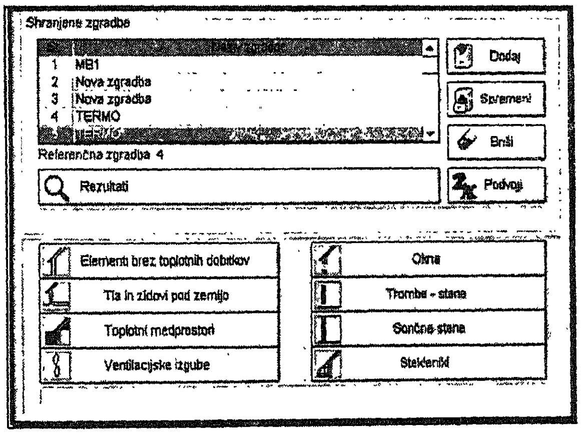
Brez upoštevanja ovir v okolici je
HGlobß: 1240 Wh/m2dan
Dir: 798 Dif: 273 Odb: 169

Z upoštevanjem ovir v okolici je
faktor zmanjšanja obsevanja HGlobß
0 76

Skupna možna dolžina osončenja je 6 h in 52 min.

Skupna dolžina osončenja je 3 h in 12 min.
Faktor senčenja direktnega sevanja je: 0.36
Faktor senčenja difuznega sevanja je: 0.72

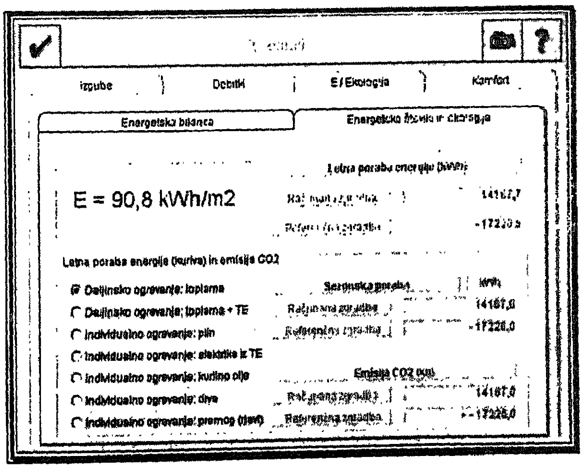
Figure 10 Window with results – reduction of direct, diffuse and albedo radiation for each month or entire year as well as sunlight duration are calculated for each observed point



1 MB1
2 Nova zgradba
3 Nova zgradba
4 TERMO

Referenčna zgradba 4

Figure 11 Input window in E^{+cad} code – various energy conservation technologies and passive systems can be analysed



E = 90,8 kWh/m2

Letna poraba energije (kWh)
[illegible] 14167,7
[illegible] 17220,5

Letna poraba energije (goriva) in emisija CO2

● Daljinsko ogrevanje: toplarna
○ Daljinsko ogrevanje: toplarna + TE
○ Individualno ogrevanje: plin
○ Individualno ogrevanje: elektrika iz TE
○ Individualno ogrevanje: kurilno olje
○ Individualno ogrevanje: drva
○ Individualno ogrevanje: premog (tlevi)

Sezonska poraba kWh
Računana zgradba 14167,0
Referenčna zgradba 17226,0

Emisija CO2 (kg)
Računana zgradba 14167,0
Referenčna zgradba 17226,0

Figure 12 Output window presenting monthly and yearly heating loads, solar gains in energy, and ecological predictions

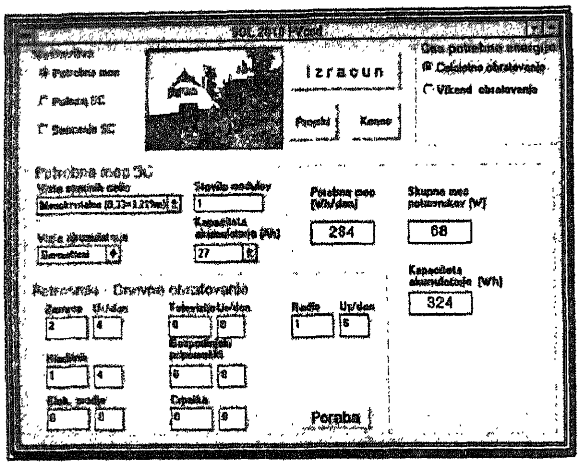


Figure 13 Basic input window of PV^{cad} code - different solar cells, accumulators, appliances, and locations can be selected, as well as monthly and weekly periods of observation

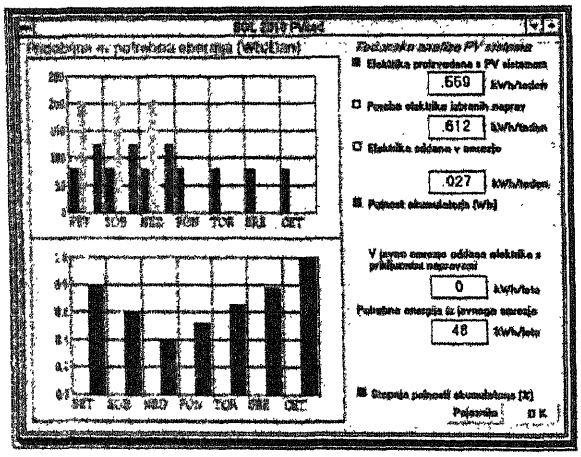


Figure 14 Output window for weekly time period for selected PV system analysed with PV^{cad}

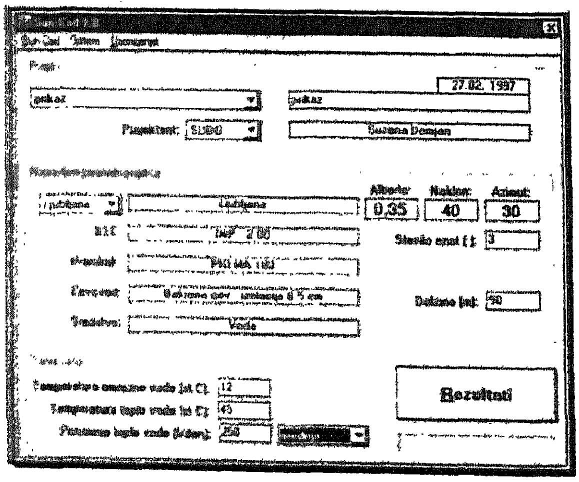
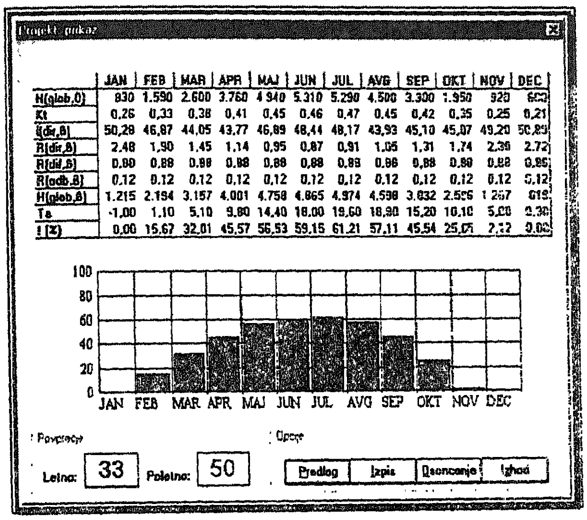


Figure 15 Input window in SUN^{cad} code showing different solar collectors, heat storage, pipes, and fluids as well as locations



	JAN	FEB	MAR	APR	MAJ	JUN	JUL	AVG	SEP	OKT	NOV	DEC
H(glob,0)	830	1.590	2.600	3.760	4 940	5.310	5.290	4.500	3.300	1.950	920	600
Kt	0,26	0,33	0.38	0,41	0,45	0,46	0,47	0.45	0,42	0.35	0.25	0,21
θ(dir,β)	50,28	46,87	44,05	43.77	46,89	48,44	48,17	43,93	45,10	45,07	49,20	50,89
R(dir,β)	2.48	1,90	1.45	1,14	0,95	0,87	0,91	1,05	1,31	1,74	2.39	2.72
R(dif,β)	0.90	0,88	0.88	0,88	0,88	0,88	0,89	0.86	0,88	0.90	0.88	0.85
R(odb,β)	0,12	0.12	0,12	0,12	0,12	0,12	0,12	0.12	0,12	0,12	0.12	0,12
H(glob,β)	1.215	2.194	3.157	4.001	4.758	4.865	4.974	4.598	3.832	2.596	1 257	619
Ta	-1,00	1.10	5.10	9.80	14.40	18.00	19,60	18,90	15,20	10.10	5,00	0.30
f (%)	0,00	15,67	32,01	45,57	56,53	59,15	61,21	57,11	45,54	25,05	2,12	0.00

Letno: 33 Poletno: 50

Figure 16 Output window with data on solar radiation and monthly and average solar fractions

Solar Engineer

Solar Engineer is a system software composed of experimental samples, sensors, a data acquisition system, and a PC (Figure 17). Using Solar Engineer, students can perform individual experiments such as:

- characterizing the solar cell as a solarimeter,
- transmittivity measurements of different transparent layers in the solar spectrum using the solar cell as a solarimeter,
- absorptivity and emissivity measurements of different opaque layers in the solar and near infra red (IR) spectra (Figure 18),
- indirect measurement of absorptivity for solar radiation by measurement of thermal response of sample absorbers on step function artificial solar radiation,
- long wavelength emissions measured with an IR sensor by comparing IR sensor readings with measured temperature of heated absorber samples, and
- steady state and transient heat transfer in small-scale solar collector and solar wall with black and selective paint absorber and transparent insulation material layer.

Each of these experiments comes with instructions on how to build experimental devices, all necessary programs for data acquisition using A/D converters and Genie software code, and manuals for analysis of the measured data using an Excel macro as well as an Excel macro for report printing. The templates for reports include measuring values, results, measuring error analyses and discussions.

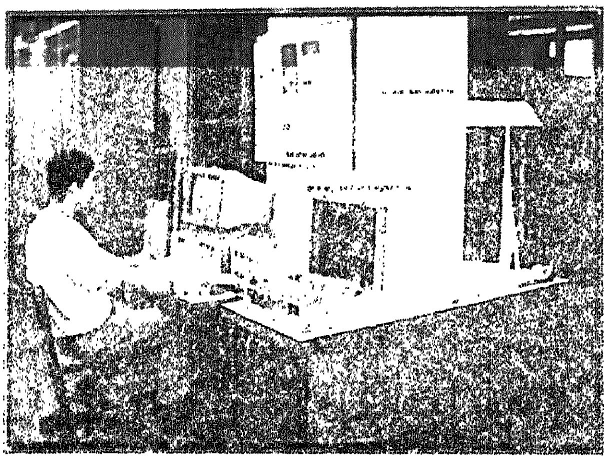


Figure 17 Student configuring a solar experiment

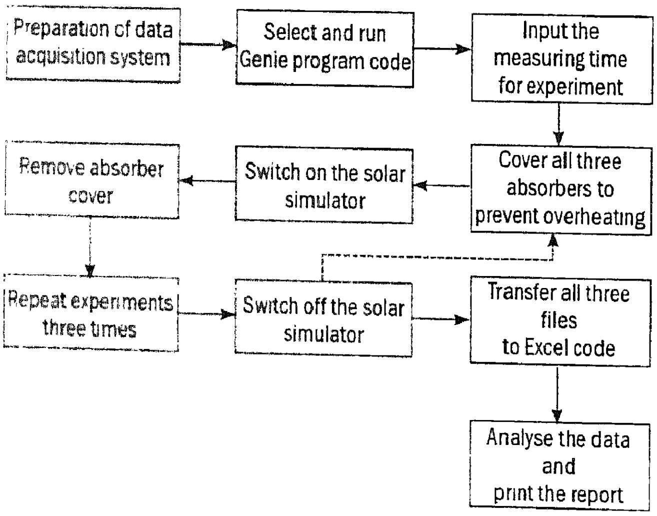

Preparation of data acquisition system
Select and run Genie program code
Input the measuring time for experiment
Cover all three absorbers to prevent overheating
Switch on the solar simulator
Remove absorber cover
Repeat experiments three times
Switch off the solar simulator
Transfer all three files to Excel code
Analyse the data and print the report

Figure 18 Logical path instructions for solar absorptivity measurements for three different absorber samples

Figure 19 shows the student working procedure with Solar Engineer: the preparation for individual experiments is made by one group with emphasis on theoretical bases of the experiment and establishment of measurement errors. Each student then performs experiments in a laboratory. Students can choose the time for performing experiments at their convenience, but they must be performed within one semester.

Conclusions

Experiences with the promotion of RE sources show that their implementation is strongly correlated with the education of all

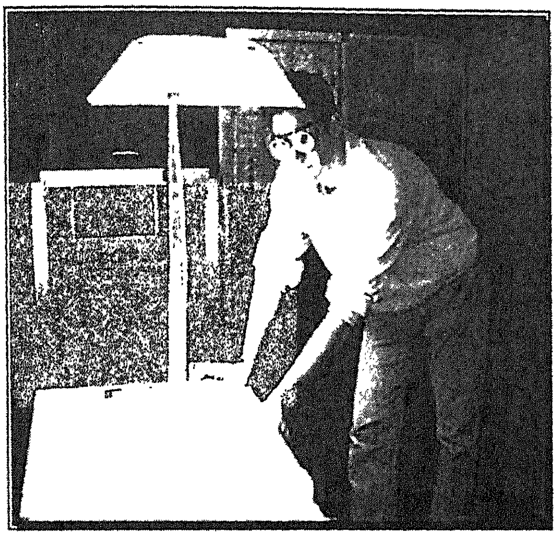


Figure 19 Student performing experiments using Solar Engineer

population groups, and therefore applies also, or especially, to undergraduate curricula. According to students' comments, the educational aids which we have presented in the paper improve the learning process from the theoretical, experimental, and engineering points of view. The understanding of the topics is rated high, with few remarks, because the students have been involved in the preparation of projects during regular study for their colleges.

In addition to improving the learning process, we hope that we will participate in the increasing popularity of engineering science as well as encourage and speed up the use of RE sources in Slovenia.

Acknowledgements
The authors would like to sincerely thank the Ministry of Economic Affairs, Government of India, the Ministry of Science and Technology, and the University of Ljubljana, Faculty of Mechanical Engineering, for their support.

Ministry of Health
and Family Welfare,
Government of India
Gate No. 31
Jawaharlal Nehru
Stadium Complex,
New Delhi -
110 003
India

S Ganesh

Press as a development tool in publicizing renewable energy education and knowledge

Renewable energy education: current scenario and future projections
pp. 262-266

Abstract

The developmental process in general, involves many factors coming into play and various inputs contributing towards development. Apart from the aid from the developed west, also needed equally are the manpower and coordination of overall development activities. Mass media in general, and the press, in particular, have an overall role to play in development. Media can contribute to provisional information, education, and enlightenment apart from providing entertainment. The specific role of press would be to stress the role of communication and act as a catalyst in initiating and in bringing about development activities. This paper stresses on the role of press media as a development tool in imparting renewable education and knowledge.

Introduction

Many inputs have gone into disseminating information and knowledge about REE (renewable energy education) among the various regions of the country. The press, no doubt, is a media that could contribute to the effective realization of RE awareness among various interest groups. Energy sources are a precious commodity and need to be effectively used, and in the event of depletion, we have to turn to alternative sources - the renewable energy sources. RE has gained momentum, and it is being given due importance in the successive plans of the government and its policies as well. Under the context, it is imperative to spell out that RE has to be popularized among the various segments of the society, especially among the educated and decision-making section of the society, who will in turn take it to the masses. This paper discusses the role of press as a development tool in REE and awareness.

Renewable energy education and the role of press

RE covers the broad spectrum of solar, wind, biomass, hydro, ocean, geothermal, and hydrogen as well as fuel cells. REE in schools and colleges and other technical educational institutions deal with these various sources. A quick look at the RE scene in India reveals the following.

India has had 16 years of renewable energy technologies deployed in many villages and cities. These include power from wind, small hydro, biomass, SPV (solar photovoltaic), power from urban and industrial wastes, and low and medium range biogas. The power generated from the above sources can never match the power obtained from burning gas, turbines, and hydel projects, but can make up the quantum with the major forms of energy as an added input. Earlier, RE was not taken seriously as it did not contribute to bulk of energy supply of the country. The main aim of this article is to highlight the role of REE, contribution of RE to the general well being of the nation, and the role of press as a development agent. RE and REE are topics related to development, and the press, in a democracy such as ours, has a pivotal role to play. Communication takes place through the exchange of symbols, ideas, and thoughts. Laymen and scholars alike think of communications taking place between two people, called interpersonal communication. When it takes place with the masses through instruments such as the press, radio, and television, it is called mass communication (Williams 1984). Press, being the media of mass communication, can play a vital role of providing information, education, and entertainment to the people. One needs to know that the press is dependent on society for news and patronage; and the society is dependant on the press. The press can cover RE as a development topic and development news. Science journalism, technology reporting, and its allied areas have gained momentum over the years, and people have fine tuned themselves to listen to these than to politics and film news. REE can also be a subject for feature writing as well. Additionally, the press can bring out special supplements focusing RE when it is a topic of discussion in academy and industry. This could go into serving the information function of the mass media. Success stories of REE can be brought out by the press periodically, targetting the likely segment of readers. Development journalism has a dominant role to play in REE. Thus, the press could set the trend for the shape of things to come, and be an eye-opener for new entrants.

The press could focus on the government's various RE projects such as the National Project on Biogas Development and the National Programme on Improved Chulhas, and disseminate information in the focus of ad dominant news source and features. Additionally, RE activities in schools can be brought to the notice of the planners, policy-makers, and decision-makers, so that, necessary financial assistance and other such services can be rendered. The press can communicate the weaknesses in REE to the concerned while taking the feedback to the planners who would rectify the situation.

Motivation is another aspect that can be dealt with by the press media (Lassawell 1969). The press media can motivate the young and old alike in the field of REE and industry, through science reporting or technical aspects and the related natural advantages. The press, through its positive coverage can help people realize the importance of REE. Such stories are not uncommon and one can find stories and features in the leading dailies like The Times of India, The Hindustan Times, and others.

The press can also play an instructional role for those preparing for various other realms of knowledge and formal education. Although the electronic media, through its coverage of topics such as building research and others, has gained easier accent and respectability, as a medium catering to the development, but, nevertheless, with its accent on literacy and knowledge, the traditional press is relatively slow. REE courses conducted in leading institution could be (coverage and content wise) reported in newspapers and magazines in the educational columns (Ganesh 1995). Through regular coverage and briefing done by the REE fraternity, the press can be enlightened to recent happenings to the growing form of scientific and technical economical activities.

Apart from the general press, the trade press or the press catering solely to RE industry and education allied to it can play a definite role in the popularization of the same. Trade press is not uncommon. It can be found in the energy sector too. Trade press of RE can play an effective role in meeting the basic expectations of the RE industry personnel. With the added input of proper guidance from the teaching faculty involved in REE, the trade press can be moulded to perform its effective role.

The number of newspapers and magazines in the country exceed 39 000 in the early 1990s with a paid circulation exceeding 65 million copies. The figures would be much higher now, and the readership and coverage of the press media continues to grow in spite of the slow growth in the overall literacy rate. Bringing REE and its development to the knowledge of common man and informing him as such could be yet another task of the press which could be helpful to the RE industry and educational scene.

Daniel Lerner's Theory of National Development also explains the role of media in national development and in the cyclic process of literacy mobilization, increased transport facilities, urbanization, and media usage. Lerner postulates that media, along with other factors, performs the vital role of transforming a traditional society into a modern one (Lerner 1958). It needs to be emphasized that the press being the agent, has a crucial role to play. In a democratic country like ours, the press performs the crucial function of serving as a watchdog for the people by keeping an eye on the activities of the government. Many scholars including Walter Lippman pointed on the role being performed by the press.

Conclusion

In our country, the press media, apart from serving the traditional role of informing, educating, and entertaining also plays a role in the popularization of REE. The general press media along with trade and technical media do have something to contribute to the overall popularity of science and technical issues pertaining to overall development. Media, in general, and press, in particular, interpret the interrelationships generally taking place in the fields of science, technology, and society as well the ongoing specific field of activity within science or technology. In many such instances, the media, and the press are being used to interpret the realms of technology, science, and society and the overall implications which result from the interaction of each of these with the society, individually and/or collectively. These studies are made in agricultural universities, research laboratories, and scientific institutions, which are located in different parts utilizing a variety of experts and laymen like (Kamath M V). The magnitude of such an activity is lesser when compared to an activity taking place in a developed society as the case with UK or USA, which cannot still be ignored together. The scientific role of press media in popularizing and propagating REE likewise need less to be stated and more left to the observers and scientific community as well as the general public to tell to their respective followers and co-workers alike in a changing world of tomorrow.

References

Ganesh S. 1995
Lectures on Mass Communication
New Delhi: Indian Publishers. 462 pp.

Kamath M V
The Journalists Handbook, pp. 106–131
New Delhi: Vikas Publishing Co.

Lassawell H D. 1969
The structure and function of communication in society
In *Mass Communication*, edited by Wilbur Schramm. 103 pp.
Illinois: Urban University of Illinois Press.

Lerner D. 1958
The Passing of Traditional Society: modernizing the Middle East
New York: GlencoFree Press.

Williams F. 1984
The New Communications
Belmont: Wadsworth.

Nucleo de Energia,
Lutheran University
of Brazil, Rua
Miguel Tostes,
101. 92420-280
Canoas (RS) Brazil

J C Vernetti dos Santos*, A Bristot, B Liberman, G Ocácia, S S Dias

Concept and design of photovoltaic systems with PV-CODE: a dedicated computer program for teaching and research purposes

Renewable energy education: current scenario and future projections
pp. 267-278

Abstract

ULBRA (The Lutheran University of Brazil), in Rio Grande do Sul, offers PPGEAM (a Graduation Programme in Energy, Environment, and Materials) for M. Sc. and doctorate degrees (created in July 1997). A group with 13 professors holding doctorate degrees forms the educational basis of the PPGEAM, in which about 50 graduate students are matriculated. The PPGEAM research lines are supported by correlated research projects. One of these projects, in cooperation with a Brazilian firm, a subsidiary of Siemens, involves research activities in the scope of PV (photovoltaic) applications for rural electrification. This project is divided into two parts: a practical one (the installation of a pilot plant) and a theoretical one (the development of a sizing method for autonomous PV systems). The results of the last one will be validated and implemented in an existent simulation program (PV-CODE).

This article presents the concept and the main features of the PV-CODE program, which is a Windows application for sizing, simulation, and economic evaluation of PV systems (standalone and hybrid). The software package consists of four main modules, which are supported by model parameter databases of each system component (PV cells, batteries, inverters, rectifiers, wind generators, and diesel generators). A component library is available. An additional module enables a statistical treatment of input/output data. All inputs can consist of measured data or can be simulated by the program. The results of all simulations are stored in text files and, after each simulation task, a summary of the results is tabulated and presented graphically. Examples of the program features are accomplished and planned developments are described.

---

* Author for correspondence

Introduction

Energy, environment, and materials are important elements of the foundation for all activities in the economic, environmental, and technological segments of the society. This fact should be considered in a holistic proposal of sustainable development.

Energy is an elementary entity that is part of all the events in the physical world. However, only the RE (renewable energy) sources, mainly those coming from the sun, have sustainability.

The environmental problems, although of great magnitude at present, can be eliminated at their sources, if society adopts a normative philosophy of sustainable development. In this sense, environmental problems must be treated in a corrective and preventive way, placing the human being as one of the central pieces of this scenery.

The variety of materials can be divided into two groups: renewable and non-renewable. Only the first ones are sustainable for the current generation as well as for the coming ones. The non-renewable materials can also be divided in two groups: the ones with small stocks (or with a short lifetime, considering the current transformation technologies, processing, and use rates), and those whose reserves have a longer life. The engineering courses should add the concept of sustainability to their curriculums by including topics like recycling, the life cycle of materials, as well as the substitution of non-renewable materials for those that have renewable characteristics.

Based on this premise, ULBRA offers the PPGEAM. A group with 13 professors holding doctorate degree forms the educational basis of the PPGEAM, in which about 50 graduate students are matriculated.

The PPGEAM research lines are supported by correlated research projects. One of these projects, in cooperation with a Brazilian firm, a subsidiary of Siemens, involves research activities in the scope of PV applications for rural electrification. This project is divided into two parts: a practical one (the installation of a pilot plant) and a theoretical one (the development of a sizing method for autonomous PV systems). The results of the last one will be validated and implemented in an existent simulation program (PV-CODE).

In a previous work, a version of the PV-CODE program was prepared in German as a result of a research project (Dos Santos 1996). It follows a description of the structure and the main features of the PV-CODE software package, as well as further planned developments and application examples.

PV-CODE structure

PV-CODE is a Windows application for the sizing and simulation of PV systems. The software package consists of four main modules that are supported with model parameter databases. An additional module enables a statistical treatment of input/output data (Figure 1).

The single program modules have their own online Help, which is available for each action in the program. Case examples for different tasks are also available in the online Help system (in a step-by-step manner).

All inputs can consist of measured data or, alternatively, they can be simulated by the program. The results of all simulations are stored in text files and, after each simulation task, a summary of the results is simultaneously tabulated and presented graphically.

The tabulated results can be copied into the Windows clipboard in text format and the graphics, as a bitmap. Consequently, these results are transferable to all Windows applications, which support the clipboard transfer with the mentioned formats.

PV-CODE comes with an installation program, with which the compressed files on diskettes are copied and expanded on the hard disk, in the selected subdirectory. A Windows program group is created, in which the program icon and the help files are inserted.

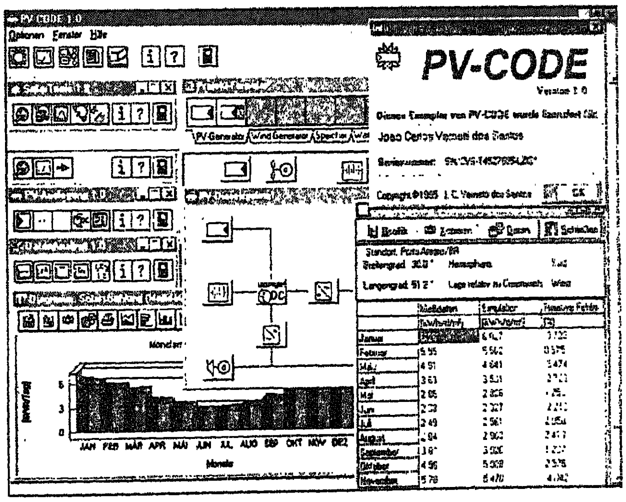


Figure 1 Visualization of PV-CODE.

PV-CODE features

The program PV-CODE offers a multiplicity of uses in areas such as meteorology, load prognosis, and system sizing and enables the definition of the system configuration, the simulation of operation of the conceived system as well as its economic evaluation. These tasks are described in the help files of the program modules. It follows a description about each program module as well as about the databases.

Libraries and parameter databases

The following databases and libraries are available.

- Monthly average of daily values of solar energy with geographical localization data
- Monthly average of daily values of energy consumption
- Monthly average of daily values of load factor
- Monthly average of daily values of ambient temperature
- Model parameters of PV-Module(one-diode model)
- Model-parameters of PV-Module (two-diode model)
- Lead batteries (Shepherd Model)
- Inverter (efficiency curve)
- Component library (with graphic visualization)
- System library (with graphic visualization)
- Specific costs functions for PV generator ($/Wp), wind generator ($/W), diesel generator ($/W), battery ($/Wh), battery charger ($/W), converters (inverter, rectifier, and rectifier–inverter set ($/W)), and additional costs ($/W)

Planned developments

- Database for frequency distribution of solar radiation measured data
- Database for monthly average of daily values of wind velocity
- Database for wind generator (characteristic curve), and water pump (characteristic curve)
- Component library (with graphic visualization): electrolyser unit, fuel cell aggregate, thermal power plants (biomass), small hydroelectric power plants, grid component, and nuclear power plant (for comparison)

Program module SolarTools

Tasks

- Synthetic generation of solar radiation data in hourly time-resolution from monthly averages of daily values of the solar radiation database. This method is based on a stochastic processes (Dos Santos 1996; Gordon, Reddy 1988; Aguiar, Collares-Pereira, Conde 1992)
- Synthetic generation of monthly daily curves of ambient temperature in hourly time-resolution from the monthly averages (ambient temperature database)
- Conversion of the horizontal solar radiation on a tilted surface with the following inputs: horizontal solar radiation in hourly time-resolution (measured or synthetic data), albedo (only one value or a value per month),

diffuse solar radiation model (Liu, Jordan 1960), isotropic model, or Perez et al. (1987) anisotropic model and tracking system options (Figure 2).

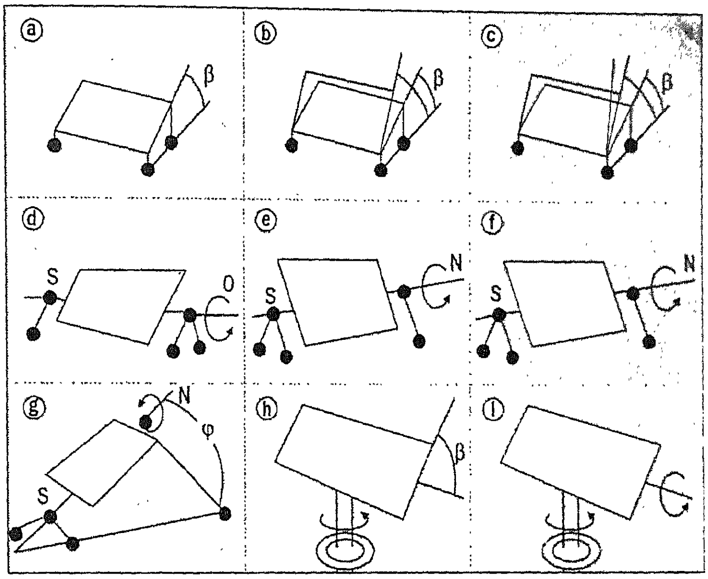


Figure 2 Photovoltaic tracking system options (Duffie, Beckman 1991) : (a) fixed tilted PV generator; (b) two fixed PV generator inclinations; (c) four fixed PV generator inclinations; (d) fixed horizontal west-east axis with an adjustment per day; (e) fixed horizontal west-east axis with continuous adjustment; (f) fixed horizontal north-south axis with continuous adjustment; (g) fixed tilted north-south axis with continuous adjustment; (h) fixed tilted PV generator mounted on a vertical axis with continuous adjustment, and (i) two axle tracking with continuous adjustment.

Note Tilt angle values can be given by the user. Alternatively, they can be automatically optimized by the simulation program, according to the annual maximum power generation criterion.

Outputs

The converted or estimated solar radiation data are stored in text files (the user chooses the file name and file destination). A summary of the results is simultaneously tabulated and presented graphically (monthly average of daily values and relative difference between input and output).

Planned developments

- Development of a model for generating synthetic sequences of wind speed data in hourly time-resolution

Program module Load Analyse

Tasks

Synthetic generation of power consumption data (Dos Santos 1996) in hourly time-resolution from monthly averages of daily values of energy consumption and load factor (both inputs are taken from two independent databases).

Outputs

The estimated power consumption data are stored in text files (the user chooses the file name and file destination). A summary of the results is simultaneously tabulated and presented graphically (monthly average of daily values and relative difference between input and output).

Planned developments

- Development of a library for consumer equipment with graphic visualization. A load profile can be defined by the user. This should be combined with the load model for generating synthetic sequences.

Program module PV Sizing

Tasks

- Simulation of the power generation of PV generators in hourly time-resolution from the following inputs: text file with solar radiation data on the generator surface (measured or synthetic data); PV generator model (one diode model or two diode model); with or without blocking diode; operating mode (MPP-tracking or fixed voltage); PV module temperature (measured data of PV module temperature in hourly time-resolution or simulated data in hourly time-resolution from daily averages of the ambient temperature or simulated hourly data from monthly averages daily averages of the ambient temperature).
- Sizing of PV systems: the system operation is figured out for every combination of the components nominal size (Dos Santos 1996). All combinations, that fill a pre-established criterion (loss-of-load probability or time operation of the back-up unit), are selected.
- Economic evaluation of the selected systems in the previous item, using a fixed value of battery time life or a variable one (Dos Santos 1996). The investment costs of all equipments can assume fixed or variable values (cost functions).
- Sensitivity analysis: variation of the input data and parameters like solar energy supply, load profile, PV module tilt, PV generator tracking system, energy efficiency of batteries and converters, depth of discharge of the

batteries, loss-of-load probability, time operation of the back-up unit, nominal size of batteries, and PV generator and back-up unit, etc.

Outputs

- The estimated nominal sizes of the components for all system combinations that fit the pre-established criteria, are stored in text files (the user chooses the file name and file destination). A summary of the results is simultaneously tabulated and presented graphically (for example, the loss-of-load curve).

Planned developments

- Development of standardized system control strategies for each system component so that any configuration is enabled.
- Development of a file format in order to store the defined configurations, substituting the current system library.

Program module Project Form

Tasks

- Conception of any system configuration (with graphic visualization) from the following components: PV generator, PV generator with integrated inverter, wind generator, diesel generator, converters (rectifier, inverter, and rectifier–inverter set), battery, battery with integrated rectifier-inverter set, battery charger, DC consumers and AC consumers. After the validation of the component connections, the component proprieties (nominal size, system control parameters, and input files) can be assigned and redefined by the user.
- Simulation of the operation behaviour of a power system conceived with the module Project Form.
- Several parameters (such as loss of load probability and time operation of diesel generators) can be estimated.
- Economic evaluation of the defined system in a similar manner as accomplished in the program module PV Sizing.

Outputs

- The estimated values of the operation data of all components of the system (for example, state of charge, battery power flow, fuel consumption of diesel generators, etc.) are stored in text files (the user chooses the file name and file destination). A summary of the technical and economic results is simultaneously tabulated and presented graphically (depending on the components of the system)

Planned developments

- Estimation and graphic visualization of the frequency distribution of the charged and discharged energy of the battery-storage.
- Development of a routine to recognize the electrical connections between components in a system configured by the user and stored in a defined file format (as mentioned above).

Program module Data Analysis

Additionally, a program module is available for simple statistical analysis of input/output data sequences. It enables the estimation of average values, standard deviations and maximum values of the data sequences with the following options: input data in daily or hourly time-resolution, as well as higher time-resolution (until 1/20 hours). The results can be obtained in the form of annual or daily sums, monthly averages of daily sums, as well as annual or monthly averages of hourly values (higher time-resolution is also possible).

Application case

Sizing parameters and procedures

In a previous work (Dos Santos 1996), sizing criteria for standalone PV systems and for hybrid PV systems with an auxiliary energy source were developed. It could be established that the loss of load probability as a criterion for PV/battery systems represents a clear relationship between the nominal sizes of PV generators and batteries, while for PV/battery systems with an auxiliary energy source the operation time of the auxiliary generator plays that role. PV-CODE will be used for the sizing of a PV system (defined below) through the accomplishment of the following tasks:

- synthetic generation of hourly averages of solar radiation data on the horizontal from monthly solar energy average;
- conversion of the synthetic generated solar radiation data on the PV generator surface;
- synthetic generation of hourly averages of power consumption data from monthly energy consumption and load factor average;
- simulation of power generation data for a preset PV generator;
- definition of the system configuration selecting single components from a components library;
- sizing the PV generator and the battery storage capacity selecting all combinations of the components nominal size, that fills a pre-established operation time of one or more diesel generators;
- economic evaluation for the sized system variants using variable annuities for the battery storage; and energy costs comparison between the existing power supply systems and the proposed hybrid systems.

Characterization of the application case

Reports (1994, 1995) of CEPEL (Brazilian Research Centre in Electrical Engineering) present the current situation (1995) of a rural electrification programme starting from renewable energy sources in 10 Brazilian states. Based on these reports, one village, São Félix of Jalapão, was selected from the State Tocantins. Table 1 presents the installed load for the village. The village has a small isolated grid supplied by diesel generators (a 20 kW unit). An increment with PV generator is planned for the system.

Table 1 Installed load power of a typical village in Brazil (values in kW)

	Lighting	Iron	Cooler	TV	Radio	Other	Total
S Felix do Jalapao	18.2	1.2	0.6	0.15	0.15	0.4	20.7

System configuration

Figure 3 shows the simplified structure of a power supply system, which makes possible the combined use of PV generators with existing diesel power plants. Two operation modes are foreseen for the system: in the first one, the diesel unit operates in order to form the grid to supply the demand when the level of solar radiation is low as well as to assist the peak loads. In the operation mode without diesel generator, a synchronous generator, acting as synchronous compensator, assumes the voltage regulation and the reactive power balance in the grid. The compensation of active power between power generation and power consumption is accomplished by the battery connected to a rectifier–inverter unit coupled to the grid.

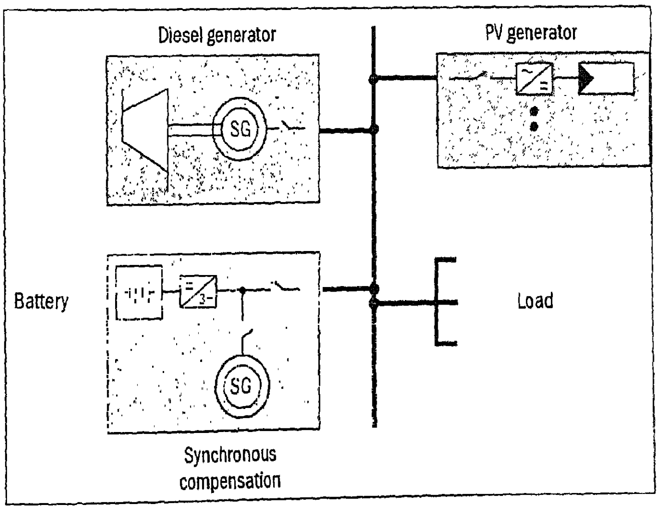


Figure 3 Simplified structure of the proposed power supply system for SÃO Félix, Jalapão

Input data (load)

From Table 1, it is possible to estimate monthly averages of energy consumption for the selected village. Schott presents a method, in which a daily load curve can be built with three different time periods: 11 hours at daytime (from 7 hours to 17 hours), 6 hours at evening (from 18 hours to 23 hours) and 7 hours at night (from 24 hours to 7 hours). Based on this method, the load factor referred to the hourly peak load can be estimated. So, it is possible to prepare the input data, since the LoadAnalyse module requires only the monthly averages of energy consumption and load factor as input data for the synthetic generation of power demand data sequences.

Input data (solar radiation)

The monthly average of daily values of solar energy was selected from the database. With this input data, it is possible to generate a solar radiation data sequence in hourly time resolution, using the SolarTools module. Since measured data at the panel surface are not available, it is necessary to employ both algebraic and empirical correlation equations, in order to estimate the solar radiation on the PV panel surface. Perez's model has been selected from the SolarTools module.

Results

Tables 2–4 show a summary of the results.

Table 2 Energy and fuel costs of the diesel system in São Félix do Jalapão. Cost considerations: diesel generator (annuity: 0.19): 1.0 DM/W; O&M/a: 0.1 DM/W; fuel costs: 1.1 DM/litre.

Diesel generator (kW)	Fuel consumption (litre/a)	Fuel costs (DM/a)	Energy costs (DM/kWh)
20	20 468.89	22 515.78	1.23

Table 3 Energy and fuel costs of the hybrid systems in São Félix do Jalapão. Cost considerations: PV generator (annuity: 0.095): 5.0 DM/Wp; PV inverter, rectifier-inverter unit, and synchronous generator (annuity: 0.095): 1.0 DM/W; diesel generator: the same as in Table 2; operation time of the diesel unit: 4000 h/a; fuel costs: 1.1 DM/litre; batteries (annuity: 0.24): 0.5 DM/Wh; energy consumption: 22945 kWh/a.

Battery (kWh)	PV generator (kWp)	Diesel generator (kW)	Fuel consumption (litre/a)	Fuel costs costs (DM/a)	Energy costs (DM/kWh)
44	8.5	20	9981.06	10 979.17	1.29

Table 4 Energy and fuel costs for the hybrid system of São Félix do Jalapão, using two diesel generators (the cost considerations are the same as adopted in Table 3)

Battery (kWh)	PV generator (kWp)	Diesel generator D1(kW)	Diesel consumption D2(kW)	Fuel costs (litre/a)	Fuel costs (DM/a)	Energy (DM/kWh)
44	8.5	15	4	6959.77	7655.74	1.15

Comparing the energy costs from Tables 2 and 3, the hybrid systems are more expensive than the ones with only diesel generators. Using the proposed hybrid systems, however, it is possible to obtain a 50% economy of fuel costs. Table 4 shows another alternative, where the diesel generator is dismembered into smaller units, allowing an improvement of system efficiency. The fuel costs are reduced to a third of the original costs and the energy costs are 6.5% less expensive.

It should be observed that power systems based on fossil fuels do not represent permanent solutions. However, they should be considered important transitory alternatives to the conventional electrification towards power systems totally based on renewable energy sources.

Conclusion

A dedicated computer program for teaching and research purposes was introduced. Developed initially for the examination of PV systems sizing parameters, the first version of this simulation programme enables the accomplishment of a multiplicity of uses in areas such as meteorology, load prognosis and sizing of power systems based on renewable energy sources. Further developments are planned, as mentioned above, facilitating for example, the energy flow analysis of a wide variety of power systems. In this way, PV-CODE becomes a suitable tool in teaching and research areas. The sizing of a hybrid PV system for a typical situation in the Brazilian rural area was accomplished to demonstrate the use flexibility of PV-CODE.

Brazil has enormous potential for using renewable energy resources, but a bulk of it is still to be tapped. PV-CODE is just a support tool for theoretical studies and it is inserted in a wider context: the PPGEAM programme represents a concrete action in this sense. An important consequence of this programme was the formulation and implementation of another graduation programme in education science (in July 1998), oriented for the sustainable development philosophy.

The main purpose is to implement the didactic pedagogical tools for the implantation of concepts about sustainable development into the educational programme of elementary schools in Rio Grande do Sul.

These concepts are related to the environment, renewable energy, sustainability, consumption, and cooperation. This new graduation programme aims to promote the change of perception and behaviour of the teachers of basic education and educational authorities in the community as well as to increase the student's knowledge of the reality of the environment in which the school is inserted.

References

Vernetti Dos Santos J C. 1996
Auslegungsverfahren von Hybridsystemen mit Photovoltaik unter besonderer Berücksichtigung der Einsatzmöglichkeiten in Brasilien
Project Report. Institut für Solare Energieversorgungstechnik, Universität-gesamthochschule Kassel, Germany.

Vernetti Dos Santos, J C. 1996
PV-Systeme zur dezentralen Energieversorgung - Auslegungskriterien und Anforderungen an Solarstrahlungs- und Verbrauchsdaten
Doctoral thesis. Universität-gesamthochschule Kassel, Germany.

Gordon J M, Reddy T A. 1998
Time series analysis of daily horizontal solar radiation
In *Solar Energy* 41(3): 215–226.

Aguiar R J, Collares-Pereira M, Conde J P. 1992
TAG: A time-dependent, autoregressive, Gaussian model for generating synthetic hourly radiation
In *Solar Energy* 49(3): 167–174.

Liu B Y H, Jordan, R C. 1960
The interrelationship and characteristic distributions of direct, diffuse, and total solar radiation
In *Solar Energy* 4: 1–19.

Perez et al. 1987
A new simplified version of the Perez diffuse radiation model for tilted surfaces
In *Solar Energy* 39: 221–231.

Duffie J A , W A Beckman. 1991
Solar Engineering of Thermal Processes, 2nd ed.
New York: John Wiley and Sons.

Session V

Renewable energy education in schools and colleges

◆

India's leadership in renewable energy development for a sustainable future
B S K Naidu

◆

Renewable energy education in school science curriculum in India
R D Shukla

◆

Renewable energy education and research programme in postgraduate level curriculums: a case study and analysis
Shahida Rafique

◆

Solar water heating systems for training and demonstration in postgraduate programmes
R L Sawhney

◆

SOLIS: Solar energy in schools
Karl Torstein Hetland

◆

Solar energy competition
Einar Oterholm

◆

Evaporative cooling of buildings in hot regions
S P Jain

Renewable energy education in schools and colleges: summary

Renewable energy education: current scenario and future projections
pp. 281-282

Chairperson

- Dr A K Dahiya
  Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development, New Delhi, India

Rapporteur

- Ms Sama Shrestha
  Centre for Rural Technology, Kathmandu, Nepal

The first speaker of the session was Prof. R L Sawhney from the School of Energy and Environment Studies, Devi Ahilya Vishwavidhalaya, Indore. He presented the findings of his survey made during the promotion campaign of solar water heating systems. He suggested improvements in tanks, pipes and fittings, controls and sensors, and heat exchangers. He also stressed the importance of the maintenance aspect and the need for appropriate site selection. This was followed by a slide show of systems with defects. Taking all the above points into consideration, he further informed that 6 improved units of solar water heating systems have now been installed at the Devi Ahilya Vishwavidyalaya campus. These units serve as experimental units as well as training and demonstration sites.

The second presenter, Mr Karl Torstein Hetland from Norway, presented a paper on *SOLIS – Solar Energy in School*. He highlighted the RE (renewable energy) projects carried out in schools of Norway. Such projects give teachers and students good examples of the application of renewables. He informed delegates that SOLIS is a National Environment Project integrated in the physics curriculum. For example, students measure the global solar irradiance, which is then transferred through computers to the laboratory. He also presented some slides on various environment-friendly technologies, for example, solar cookers, solar ponds, solar photovoltaics for electricity generation and running computers, solar-driven cars, solar showers, solar bikes, solar hats, etc.

Mr Einar Oterholm from Norway was the third presenter, with a paper on *Solar Energy Competition*. He informed delegates that his projects invite participation from from kindergarten levels to university levels. Projects like *Our Wonderful Sun* (1996/97), *SunDay* (1997) and *Further Development of Our Wonderful Sun* (1998) have given students, teachers, and parents good exposure not only on solar energy but also on the application of all RE sources. He explained that the literature available to students like simple booklets illustrate good teaching ideas. He also explained that the students are encouraged in *learning by doing*. In 1998, more than 70 teachers participated in a workshop on the utilization of solar, wind, and bioenergy. Massive awareness campaigns incorporating the elements of song, dance, poetry, theatre, lectures, etc. have created immense enthusiasm about RE not only in the school but also in the entire community.

Finally, Prof. S P Jain from the Centre for Research Developments, Roorkee University, presented his paper on *Evaporative cooling of buildings in hot regions*. He emphasized on three technologies: (1) natural cooling by natural resources: roof surface evaporation, (2) natural heat insulation for cooling and waterproofing roofs, and (3) natural system for improving the thermal performance of brick walls.

Rural
Electrification
Corporation
Limited,
SCOPE Complex
Lodhi Road
New Delhi -
110 003
India

B S K Naidu*

India's leadership in renewable energy development for a sustainable future

Renewable energy education: current scenario and future projections
pp. 283-298

Abstract

India has been recognized as a new wind superpower[1] ranking fourth in the world with respect to wind power installed capacity. It also ranks 10th in hydro power capacity. India has the world's second largest capacity to manufacture solar photovoltaic crystalline modules. It is the largest producer of cane sugar in the world as well, thereby holding the highest potential for bagasse-based cogeneration. India's programme of renewable energy development is being reported as the second most extensive in the developing countries, next only to China. It is, therefore, visibly moving towards global leadership in the renewable energy movement. India is the only country in the world to have an exclusive Ministry of Non-conventional Energy Sources which has created a conducive environment to facilitate accelerated development of environment-friendly renewable energy technologies.

This paper[2] examines renewable energy potential in India, with a focus on the electricity sector. It explores the possibilities of tailoring renewable energies to ecologically favourable development in the country. A sectoral analysis leads to a set of strategies and policy initiatives for increased utilization of renewables within the 'total energy mix' that is more favourably disposed towards sustainable development.

---

[1] This is an updated version of the paper published in 1996 in *Energy Policy* 24(6)

[2] According to Worldwatch Institute (1998)

---

* Former Executive Director, IREDA (Indian Renewable Energy Development Agency), New Delhi

Introduction

'Sustainable development' is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It is necessary to realize that sustainable development is more than just 'environment conservation'. It is essentially 'development' that is environmentally, socially, and economically sustainable.

Energy for development

Energy is the 'prime mover' in the development process. Depleting fossil fuel resources cannot prime the growth process that is sustainable. They need to be gradually replaced by renewable sources of energy, which are perennial in nature. The sun is the source of all renewable energies. While solar energy is radiated directly to earth's surface, it also manifests itself in several indirect forms such as wind energy, hydro power, ocean thermal energy, bioenergy, etc. This naturally 'recycled' resource-base must to be utilized to meet the energy demand of the exponentially growing world population which is likely to touch the 10 billion mark by 2050, of which nearly 2 billion will be that of India alone.

The present energy-mix and its environmental implications

Of the world's commercial primary energy supply, 85% is supplied by fossil fuels. Conventional (renewable) hydro, nuclear, and new renewable energy sources provide the rest (Table 1).

Table 1 Global commercial energy supply

Energy source	Percentage of total supply
Fossil fuels	85
Hydro power	9
Nuclear energy	4
New renewable energy	2

The fossil non-renewable path of power generation, however, may not take us too far with the present rate of consumption (Table 2).

Table 2 Lifespan energy (with the 1996 rate of consumption)

Energy source	World	India
Coal	228	245
Oil	43	21
Gas	65	38
Nuclear	80	> 100

The actual rate of fossil consumption fuels is expected to multiply with the exponential growth of population and their aspirations. Long-term 'energy security' cannot, therefore, be assured by non-renewable energy sources only. Besides exhausting the fixed stocks, the fossil route has serious environmental repercussions since CO_2, SO_2, NO_x, and fly ash are cogenerated along with electricity. The production and consumption pattern of the thermal plants in India with an installed capacity of 64 150 MW is detailed below.

1. Production
   - Electricity: 320 billion kWh
   - Fly ash: 75 MT (million tonnes)
   - CO_2: 290 MT
   - SO_2: 2.25 MT
   - NO_x: 1.71 MT
   - Heat: three times the energy produced
2. Consumption
   - Coal: 192 MT
   - Oil: 310 million litres
   - Water: 2890 billion litres
   - Diesel/coal for transportation of coal

In spite of such a production–consumption pattern, thermal plants continue to have the largest share in power production globally and in India too as seen in Figure 1.

Global attention is now turning towards the greater use of renewables as warnings about the earth becoming a warmer greenhouse become persisitent and louder.

The energy dilemma

About one and a half centuries ago, a lack of focus on renewables, clubbed with population explosion, has led to a crisis situation.

1. There is an energy deficit on a global scale.
2. The energy deficit is set to increase further with the growing demands of an exploding population.
3. Non-renewable energy technologies are available on a commercial scale but the present rate of their dissemination will not be able to check
   - the fast depletion of the fixed stock of fossil fuels
   - serious environmental repercussions like greenhouse gas emission, acid rain, etc.; and
   - fossil fuel rich countries demanding higher costs for their resources from the have-nots.
4. Renewable energy sources, though available in plenty, cannot be immediately included into the energy mix as alternatives. This is because

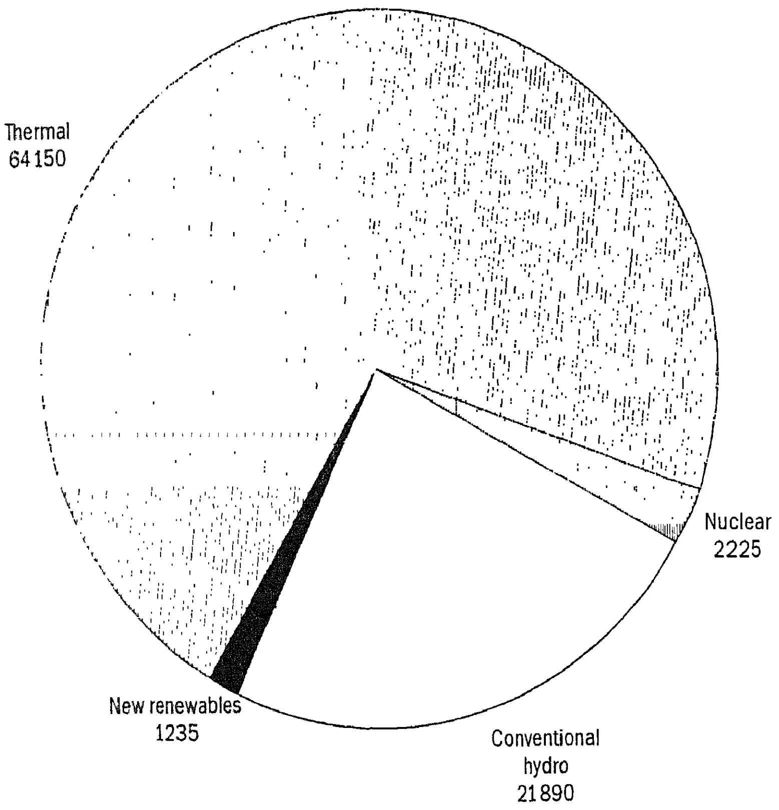


Figure 1 India's installed electric capacity (grid connected as on 31 March 1998; total installed capacity ~89 500 MW)

- suitable technologies for harnessing renewables economically are not readily available,
- generating awareness, mobilizing policy support, and evolution of institutional mechanisms is going to take, time, and
- they are less attractive economically as compared to conventional alternatives (ignoring the environmental and social costs).

In order to develop various forms of renewable energy, continuing technical innovation is necessary. Economic systems that do not provide for competition and incentives cannot command efficiency and growth.

Although CO_2 emissions are bound to increase in the next century, environmental concerns with local and regional impacts for most countries have a higher priority than the predicted greenhouse effect. Therefore, energy conservation with determined efforts to improve energy efficiency and the timely prudent adaptation of these measures should be the most practical response against the negative impacts from a possible global climate change. The key for reconciling the need for more energy with the need to protect the environment is, therefore, 'improving energy efficiency' and 'turning towards renewables more seriously'.

enewable nergy in ndia

India is blessed with abundant solar energy, equivalent to 5000 trillion kWh per annum besides several indirect forms of solar energy manifested as hydro power, ocean energy, wind energy, bio energy etc. Table 3 lists the renewable energy sources together with their estimated potential in India.

Table 3 Renewable energy potential in India

Energy source	Estimated potential (MW)
Solar energy (MW/ km^2)	20 (5×10^{15} kWh/year)
Hydro power	84 000
Small hydro	10 000
Ocean thermal power	50 000
Sea wave power	20 000
Tidal power	10 000
Wind energy	20 000
Biomass including cogeneration	17 000
Draught animal power	30 000
Energy from waste	1700

In the last 10 years or so, RETs (renewable energy technologies) in India have been promoted through R&D, demonstration projects, and dissemination projects/ programmes and facilitated by government subsidies and fiscal incentives. The growth in different sectors as of March 1998 is listed in Table 4.

Though the above figures seem to be impressive in themselves, the contribution of renewable energy has not been significant enough in the overall energy scenario, the major reason being that they are economically unviable compared to conventional sources due to technological and other constraints and low budgetary allocations (less than one per cent of the energy sector). Of late, with some of the technologies maturing fast and the government's initiatives to provide a conducive policy environment and support mechanisms for private sector participation in the renewable energy sector, positive signs are evident in faster pace of development and inflow of private funds (as much as Rs 10 for each Re 1 in the budget in some sectors) for the same.

Table 4 Growth of renewable energy technologies in India (cumulative achievement up to March 1998)

Programme	Achievement
Wind energy	
Windfarms (MW)	970
Small hydro	
Mini-micro (up to 3 MW)	155.38
Bioenergy	
Biomass power including cogeneration (export) (MW)	110
Biomass gasifiers/stirling engines (MW)	37
Family-size biogas plants	2.713
Community night-soil biogas plants (MW)	2300
Improved cookstoves	28.49
Biofuel-supported vehicles	578
Solar thermal	
Solar thermal systems (collector area 40 000m^2)	
(million litres per day)	20.5
Solar cookers	456674
Solar PV (45 million systems)	32
Grid-connected voltage support (KW)	
and peak shaving systems	810
PV power packs (2 kW to 10 kW)	1054
PV domestic lighting units	64 565
PV lanterns	1 65 393
PV streetlights	32 708
PV water pumps	2481
Others	
Hybrid systems (KW)	35
Energy from waste (MW)	3.75
Battery-operated vehicles	207
Energy parks	140
Urjagram projects	256

Source MNES (1998)

Environmental scanning for renewables

A comprehensive perspective on renewable energy can be conceived through environmental scanning. No sector of development operates in a vacuum. It derives its existence from the political, economic, social, and ecological environments. The SWOT (strengths, weaknesses, opportunities, and threats) analysis is an important tool for environment scanning by which we synthesize all the conceptual parameters.

Renewable energy: SWOT analysis

Strengths

- Unlimited/perennial potential
- Environmentally benign
- Favoured option for sustainable development

- Favoured option for social justice ensuring equitable distribution of benefits
- Naturally recycled resource base
- Renewable energy plants and devices are modular even in smaller ratings

Weaknesses

- Availability of energy is seasonal and intermittent
- Renewable energy sources are usually low-density energies requiring larger areas of space
- It imposes a greater demand on labour
- Financial viability in question, particularly with respect to other conventional energy supply systems
- Non-conventional energy is costlier and much more capital intensive than conventional energy systems per unit capacity of installation
- Due to the abovementioned disadvantages, only few RETs can replace conventional, fossil-fuel based resources competitively
- Due to the low density and inconsistency of supply, the capacity utilization of these systems is lower

Opportunities

- Environment-driven awareness
- Policy initiatives at global and national levels.
- Short gestation schemes
- Less lead time, quicker implementation of projects
- Easy to install 'stand-alone' systems
- Provides opportunities for electrification of rural areas
- Generates employment in rural areas
- In most cases the cost of transportation of fuel is eliminated
- Cost of other inputs is also considerably reduced
- Social benefits accrue out of the installation and utilization of RETs
- Can be matched to the scale of the need

Threats

- If the environment-driven momentum is lost, the thrust on renewable energy would die down
- If social and environmental costs are not looked into, renewable energy would remain secondary to conventional energy
- Enough R&D back-up is missing in a rush for the fast commercialization of these technologies prompted by incentives
- Incentive/subsidy driven momentum could be temporary

Tailoring renewable energy to sustainable development

In India, energy demand is increasing at the rate of nine per cent per annum and supply is not keeping pace. Present deficit of electrical energy is eight per cent and that of peaking power is 11%. The hydro–thermal mix in power generation is 25:75, representing an environmentally unkind model and a deficit situation particularly in peaking power. A study indicates that India would have to spend Rs 860 billion annually by the year 2020 just to satisfy its energy demand, if the existing undesirable energy-use pattern persists. While the national power grid may be necessary for transmitting huge amounts of power from one region to the other, non-grid connected stand-alone systems would still be required to serve the large number of villages and isolated communities in India. In the larger interest of sustainable development, certain regulations may be necessary to ensure a correct balance between the factors such as:

- centralized generation/grid supply versus decentralized generation/off-grid supply;
- new generating capacity versus energy conservation/ demand-side management;
- short-term solutions for power versus more sustainable long-term options;
- polluting energy sources versus environment friendly options; and
- non-renewable energy versus renewable energy.

The country had ambitious targets for generating 2000 MW of power from renewable energies during the Eighth Plan (1992–97), sectoral break-up of which is given in Table 5 together with achievements by the end of the plan and also as of March 1998.

Table 5 Eighth Plan capacity addition programme through renewables

Sector	Capacity addition (MW) Targeted	Capacity addition (MW) Achieved	Beyond Eighth Plan (achieved as of March 1998)
Small hydro power (< 3 MW)	600	141	155
Wind power	500	900	970
Biomass power including cogeneration	800	84	110
Solar thermal electric	30	–	–
Solar photovoltaics	25	28	32
Others (gasifiers, etc.)	45	22	37
Total	2000	1175	1304 ≈ 1300

Sectoral review

Hydro power

Hydro power represents non-consumptive, non-polluting use of water resources towards inflation-free 'highest density' renewable energy development with the most mature technology, highest 'prime moving' efficiency, spectacular operational flexibility, and multifarious incidental benefits. Massive gravitating influx of surface water unleashed by the hydrological cycle has an estimated technical potential of 20000 billion units/year, of which 10000 billion units/year are economically feasible. Of this only 30% has been harnessed so far. India's hydro power potential is estimated at 84 000 MW at 60% load factor (or 1 35 000 MW at 40% load factor). The annual energy contribution of this potential would be about 600 billion units. Around 15% of the country's potential has been tapped so far through 21 890 MW installed capacity.

Small hydro

Worldwide, less than 10 MW station capacity hydro plants are classified as 'small hydro'. The currently installed small hydro capacity globally is about 47 000 MW and is expected to increase by 1000 MW each year until 2020. In India 'small hydro' covers station capacity up to 15 MW and potential for the same is estimated around 10 000 MW. The status of implementation as of March 1998 is shown in Table 6.

Table 6 Installed capacity of small hydro in India

Capacity range	Installed	Under construction
Up to 3 MW	155	230
3 < MW < 15	430	135
Total	585	365
Grand total (MW)	950	–

Of the above, development of mini hydels up to 3 MW capacity on canal drops, dam toe, and run-of-river sites is an area of considerable interest. Offers for over 350 MW from the private sector are in the pipeline. Decentralized generation through 'stand-alone' systems in the hilly regions with the full involvement of local communities and NGOs (Non-government organizations), is receiving particular attention. A UNDP–GEF (United Nations Development Programme–Global Environment Facility) project on mini-micro hilly hydels in 13 states of the Himalayan region and a scheme on 'portable micro hydels' in 7 north/north-eastern states have also been taken up through TERI and IREDA in New Delhi.

Ocean energy

Seas and oceans, which cover about three-fourths of our planet, are vast reservoirs of energy. Ocean energy is available in thermal gradients, waves, and tides.

Ocean thermal power

A temperature difference of nearly 20 °C between the warm surface water and the deep cold water (at depths of 1 to 2 km) in tropical oceans such as the Indian Ocean is sufficient to generate electric power. The OTEC (ocean thermal energy conversion) process essentially consists of evaporating a working fluid such as ammonia or freon by the use of a heat exchanger, which drives a turbine generator to produce electricity. OTEC demonstration plants of 250 kW and 32 kW are working in Hawaii (USA) and Nauru (Japan), respectively. The Indian Ocean has a vast potential of 50 000 MW. There is an enormous potential to tap this renewable source of energy. Sea Solar Power, USA, and the Tamil Nadu Electricity Board, India, have signed an MoU (memorandum of understanding) in 1994 to install the world's largest OTEC plant of 600 MW (100 MW in the first phase at a cost of $250 million) at Kulasekarapatnam near Tiruchendur in Tamil Nadu.

Sea wave power

Oscillating water column plants have been developed to capture wave energy. Currently, 500 kW of grid-connected wave power generating capacity is operating worldwide, the most important being the 350 kW Tapered Channel Plant at Toftestallen, Norway, operating since 1986. Other small plants are operating in Japan, UK, etc. A megawatt plant is under construction in Australia. In India, with the potential as high as 20 000 MW, harnessing of wave energy is being explored by Sea Power AB of Sweden. A demonstration unit of 150 kW was installed by the Kerala State Electricity Board in technical collaboration with the Indian Institute of Technology, Chennai, in 1993 at Vizhinjam (Kovalam Beach) near Thiruvananthapuram.

Tidal power

The earth's gravitational pull generates oscillating oceanic tides which keep billions of litres of water on the move as it builds up and recedes twice a day. According to the National Oceanographic and Atmospheric Administration, USA, the potential energy of tides is estimated at 3 × 106 MW. About one-third of this power is dissipated in shallow seas. This implies that the exploitable energy available on sea coasts is of the order of 106 MW. It is techno-economically possible to generate 500 billion units annually from the tides. Presently, 265 MW of tidal plants are under operation in France, Canada, Russia, and China, the most important of them being

240 MW in La Rance plant in France, operating since 1966. India has a long coastline but the gulfs where tides get pronounced thereby becoming suitable for moving the bulb turbines are only a few. The sites have been identified in the Gulf of Kutch, Cambay, and Sunderbans with average tides of 3–7 m height and with a cumulative power potential of nearly 10 000 MW. The Kutch Tidal Project, which will generate 900 MW (1690 million kWh/year), has already been investigated by the Central Electricity Authority. Its implementation has been entrusted to the National Hydro-electric Power Corporation, India.

Wind energy

Global technical wind power potential is estimated at about 20 000 billion units/year, which is twice the present world electricity production. Present global installed capacity is around 7636 MW producing 12 billion units per annum with an average capacity factor of 20%. America shares 1680 MW while Europe has 4794 MW. Europe is planning for 100 000 MW wind capacity by 2030.

India is implementing the world's largest wind resource assessment programme covering over 600 stations in 25 states. A wind power capacity of 970 MW has already been installed up to March 1998 (Table 7), which has placed India among the top four countries in the world.

Besides the above, a capacity of over 2000 MW is in the pipeline. The goal of 500 MW in the Eighth Plan (1992–97) had already been exceeded in 1995 itself. According to a recent report of the consulting firm, Arthur D Little, India will lead all the other countries, outside the US, in the projections for the creation of wind power capacity by the turn of

Table 7 Installed capacity of wind power in India (MW)

Year	Demonstration projects	Private sector projects
Seventh Plan (1987-92)	32.2	–
1990/92	2.4	6.5
1992/93	3.2	9.5
1993/94	2.0	59.1
1994/95	4.2	231.3
1995/96	4.0	378.1
1996/97	3.0	164.8
1997/98	–	69.6
Total	51.1	918.9
Grand total	970	

the century, by 1200 MW. Around 24 manufacturers are engaged in the assembly and production of wind turbines in India. A national wind test centre is being established in Tamil Nadu, India with the assistance of the UNDP and DANIDA (Danish International Development Agency). Another test station is being planned in Gujarat by TERI in collaboration with the ECN (Netherlands Energy Research Foundation).

Solar energy

Globally, around 350 MW PV capacity (12% grid connected) and over 350 MW solar thermal power capacity has been created. In India, both solar PV as well as solar thermal routes are being considered, with a view to establish a sound technology base and manufacturing capacity, and to provide operational experience to utilities and industrial users. Solar PV capacity of nearly 32 MW has already been created through power units, community and street lights, domestic lighting including lanterns, and PV water pumps, etc. Two 100 kW partially grid connected solar PV projects under village electrification are now operational. There is considerable interest among manufacturers and developers to take up PV projects. The Eighth Plan target of 25 MW has already been exceeded. A 35 MW solar thermal power project based on line focusing on parabolic collectors is proposed to be taken up at a cost of US $100 million with the GEF/World Bank financing at Maithania, Rajasthan. The project would use oil fired back-up as conceived by the BHEL (Bharat Heavy Electricals Ltd) who have already prepared the detailed project report and are expected to execute the project. The National Environmental Engineering Research Institute, Nagpur, is studying the environmental impacts. Solar thermal water heating systems with an aggregate collector area of over 410 000 m^2 equivalent to 20 million litres per day capacity have already been installed.

Bioenergy

The use of biomass has dominated the world energy scene since the beginning of mankind, and continues to do so for a large part of the rural population in many developing countries. Photosynthesis provides 120 billion tonnes of biomass every year, corresponding to about five times the world's total energy need. Today, approximately 14% of the world's energy supply today is from biomass. There are several routes of converting biomass into a usable energy form. The most conventional form is to burn it to produce heat. Bio-ethanol and bio-diesel are now produced which can be used to fuel cars. A more promising route is gasification and/or burning it in fluidized bed boilers. Briquetting, which uses bio-coal in conventional boilers is also gaining ground. Biomass briquettes are equivalent to 'B-grade' coal (3800 kcal/kg) in terms of heat value. Energy plantation, with a predicted crop yield of 15 tonnes of dry poplar/per hectare/year, can lead to an electricity production of about 30 000 kWh/hectare/year. India generates a large amount of biomass material which can be utilized for power generation. Agricultural waste itself is estimated around 400 MT per year. Programmes are also being developed for direct combustion and grid interactive gasification using woody biomass or agricultural residues such as crop straws, stalks, and husk.

Cogeneration

An important programme has been launched in bagasse cogeneration aimed at optimizing surplus power generation through the upgradation of boiler pressures and improving efficiencies. Cogeneration capacity capable of exporting 84 MW surplus power having been established, projects aggregating to 225 MW are being firmed up. A USAID/GEF (United State Agency for International Development) project has been approved for off-season alternative biomass cogeneration.

Draught animal power

India is an agricultural country and draught animals play a dominant role in the nation's rural economy. Over 80 million draught animals available in the country are capable of producing energy equivalent to 40 million h.p. or 30 000 MW of electricity, which is equivalent to 50 000 million units per annum worth Rs 100 000 million. More than 65% of energy used in agriculture is from animal power. This enormous power potential can be optimized by upgrading draught animal power systems like efficient carts, harnessing devices, etc.

Financing of renewable energy

A favourable fiscal/policy environment exists in India for the development of renewable energy sources economically. In the last 10 years, RETs in India have been promoted through R&D, demonstration projects, and dissemination projects/programmes and facilitated by the government subsidies and fiscal incentives outlined below.

Fiscal incentives

1. From the central government
    - Income tax holiday
    - Accelerated depreciation
    - Concessional custom duty/duty-free import
    - Capital/interest subsidy
2. From state governments
    - Energy buyback, power wheeling, and banking facilities

- Sales tax concession/benefits
- Electricity tax exemption
- Demand cut concession offered to industrial consumers who establish power generating units from renewable energy sources
- Capital subsidy

Table 8 gives of installation and of generation costs of some of the more important renewable energy projects.

Table 8 Installation and generation costs of different renewable energy technologies

Sector	Capital cost per MW (million rupees)	Cost of generation per kWh (Rs)
Small hydro	30-50	1.00-1.50
Wind energy	35-40	2.00-2.75
Biomass power	30-40	1.75-2.00
Bagasse cogeneration	25	1.25-1.50
Biomass gasification	25	1.25-1.50
Solar photovoltaic	300	10.00-12.00

Table 9 illustrates why new and renewable sources of energy should be opted for by private developers, banking/financing institutions, and the state as such. It also spells out the constraints and the possible support/solutions.

Strategy for increased utilization of renewable energy sources

The following suggestions have been made for increasing the share of renewables and for their gradual transition from mere 'additives' to 'alternatives' within the total energy mix.

- Create awareness and respect for decentralized standalone energy systems operating on renewable resources.
- Develop an appropriate policy package throughout the country for private sector participation in producing grid quality power from renewable sources.
- Promote a 'renewable energy movement' through cooperatives and community-based networks.
- Develop entrepreneurship in the renewable energy sector.
- See renewable energy development not as merely an energy augmentation effort but as an instrument for social justice. It may be classified as a socially-oriented activity for plan fund allocations and priority sector lending.
- Provide 'level playing ground' for renewables, in terms of fund mobilization, institutional support, and tariff formu-

Table 9 Power from new and renewable sources of energy

Parameter	Private developer	Bank/financial institution	Country/State
Perception	▪ Small-scale power development suitable to small/medium entrepreneurs ▪ Meeting the power shortage to some extent ▪ Freezing of power cost for captive consumption	▪ Support an emerging sector and also earn ▪ Making the viability better for the private developers through soft loan assitance ▪ Supporting basic infrastructure for industrialization	▪ Sustainability ▪ Environmental conservation ▪ Give a fillip to otherwise slow growth technologies ▪ Additional resource mobilization ▪ Short gestation ▪ Decentralized power generation for rural masses ▪ Rising liability on import of diesel etc.
Constraints	▪ Financing support still required ▪ Marginal viability ▪ Low capacity utilization ▪ Technical know-how for construction operation and maintenance ▪ Risk and uncertainty on new technologies	▪ Delicate balance between development and commercial role ▪ Technologies yet to reach a level of commercialization beyond doubt	▪ Low density and seasonal sources, location-specific ▪ Lack of technological maturity/R&D back-up
Solution/ support	▪ Joint venture/collaboration ▪ Lobbying to get benefits	▪ Co-financing for risk sharing ▪ Liberal financing of equipment manufacturing	▪ Policy support ▪ Favourable response from state electricity boards

lation, keeping in view the 'avoided costs' and delivery price of energy. Encouragement to continue through financial incentives, tax rebates, etc., for their environmental virtues.

- Constitute a 'renewable energy act' that addresses the concerns of renewables and covers all their statutory aspects so as to bring them on a fast-track development frame.
- Intensify R&D efforts to improve the technology of renewables and bring them at par with conventional energy systems.
- Create a national-level 'renewable energy development corporation' to plan, promote, and organize renewable energy development on a massive scale throughout the country.
- Mandate large-scale power generating companies ($\geq$ 100 MW) to generate/fund at least 10% of their capacity through renewables.
- Stimulate increased uptake of renewables through non-fossil fuel obligation. Levy 'sustainability tax' on each unit of power generated from non-renewables to generate a fund for renewables as an investment for the future.

Renewable energy education

Conclusion

India is one among the very few developing countries which have embarked upon an environmentally conscious development path and has launched policy initiatives to accelerate renewable energy development for sustainability. Having achieved 1300 MW (1235 MW grid connected) of renewable electric capacity during 1992–98, India has a place of pride in the world to have added over seven per cent share of renewables in its capacity addition programme in a span of six years. It has ambitious plans to continue renewable electric capacity addition to take it to a respectable share of 10% of grid power by 2012. Prospects for renewables are steadily improving in India, which is poised to take a leading role in the 'global renewable energy movement' aiming towards sustainable development.

References

MNES. 1998
Annual Report 1997–98
New Delhi: Ministry of Non-conventional Energy Source, Government of India

Worldwatch Institute. 1998
The State of the World Report 1998
Washington D C: Worldwatch Institute.

National Council
for Education,
Research and
Training,
Sri Aurobindo Marg
New Delhi -
110 016
India

R D Shukla*, V P Srivastava

Renewable energy education in school science curriculum in India

Renewable energy education: current scenario and future projections
pp. 299-306

Abstract

According to the National Policy of Education, 1986 (India), science teaching is a compulsory component of 10 years of schooling with an objective to create scientific literacy among children and make them conversant with various national problems like energy and environment. A conscious effort has been made to develop awareness about RE (renewable energy) through school science curriculums. An in-depth study of the present curriculum of various school levels reveals that an adequate quantum of REE has been provided. The present paper provides a complete analysis of REE components, beginning with a very simple picture of energy (at the primary level) and going further into various scientific ways of harnessing RE sources (at the senior secondary level). The paper further discusses non-formal methods of generating awareness about RE. New strategies for promoting REE at the school level have also been outlined.

---

* Author for correspondence

Introduction

We are aware that the standard of life and the prosperity of a nation are reflected, to a great extent, by the amount of energy consumed by its population. Though, by this standard, India is a backward country, even with the present rate of consumption, which cannot remain static with the growing population and its aspirations, it will exhaust all its oil and gas by 2050, and so will the entire world. With the limited reserves of conventional sources of energy and the environmental problems associated with their use, concerted efforts, similar to those in other nations of the world, are being made in India for developing new methods and technologies to harness renewable sources of energy in an efficient manner. It is now a well-accepted fact that the future energy scenario, that is truly compatible with the achievement of a sustainable world, must, in the long run, be based on the use of RE resources. This has made energy an essential topic in school science curriculums. In fact, education in energy should form an essential component of not only science education, but also of general education so that it becomes a part of everyone's school experience. The basic philosophy behind making science compulsory up to 10 years of national education, according to the National Policy of Education (1986), subsequently renewed in 1992, is to prepare a child to be a good, knowledgeable citizen of the country instead of merely a scientist/technologist or an engineer. Science education is for providing scientific literacy to students so that they understand and appreciate the problems of the country. For example, the ability to understand one's electricity bill; to know the difference between kW and kWh; and to be sufficiently informed to recognize the link between electricity consumption, coal production, and global warming is as much part of the essential component of common knowledge as are the skills of literacy. Teaching students about energy resources will help them grow into informed adults capable of making intelligent decisions about the use of such resources. Further, they will also be able to influence the formulation of wise energy resource policies.

Therefore, a plan should be designed to educate students about the critical role played by energy and energy resources in every aspect of our daily life and society. There are two channels through which energy education can be imparted at the school level. The first is through a formal curriculum and the second, which is in no way less important, is through a non-formal way or out-of-school activities. There is no doubt that children also learn through interaction with their natural and physical environment, particularly their family, the media, and the surroundings.

Let us now analyse the present science curriculum of various stages of school education and out-of-school activities to find out the extent to which REE (renewable energy education) is imparted to school children.

Present status of renewable energy education in school curriculum

In order to discuss the place given to REE in the school science curriculum, it would be better to examine the curriculum in stages, i.e., (1) elementary level (comprising primary and upper primary from class I to VIII), (2) secondary level (class IX and X), and (3) senior secondary level (class XI and XII).

Elementary level

Energy is introduced in school science at an early stage in the curriculum. In class IV, it is first talked about in the chapter on work, force, and energy. Here, the students are exposed to the concept of energy in relation to work and force, in a qualitative way. Two forms of energy, namely heat and electricity, are introduced in brief. The students are also told that the sun is the ultimate source of energy and other sources like oil, coal, gas, etc. are limited. The discussion about energy continues in the next class as well wherein coal, oil, and electricity are talked about. Once again it is emphasized that the existing sources of energy are limited and will not last longer and therefore, we must look for other sources. It is here, for the first time, that the need and concept of alternate sources of energy is introduced in the curriculum. Under this category, wind, solar, and biogas are discussed in brief. The topic evolves into a full chapter on energy in class VI. At this level, different sources of energy are classified into renewable or non-renewable.

So one can say that the concept of RE is introduced in class VI. Students learn not only the science but also the technology involved in harnessing solar energy, wind energy, hydroelectric energy, and biomass energy. The uses and designs of windmills and water wheels are discussed in brief. The theme of RE is further elaborated in class VII. At this stage, not only is energy from the Sun talked about, but a very important aspect of RE is also taken up – the *management of energy needs*. The discussion on energy, starting in class IV, culminates into a full-fledged chapter on alternate sources of energy in class VIII, where the focus is on RE. The importance and uses of different types of RE are covered. Energy from the sun and methods to harness it through solar cookers and solar heaters are discussed. Students are taught about energy from biogas and biomass. At the elementary stage, the concept of energy and the different forms of energy are introduced, and the topic evolves into renewable sources of energy. This progression of concepts and their linkage is schematically shown in Figure 1.

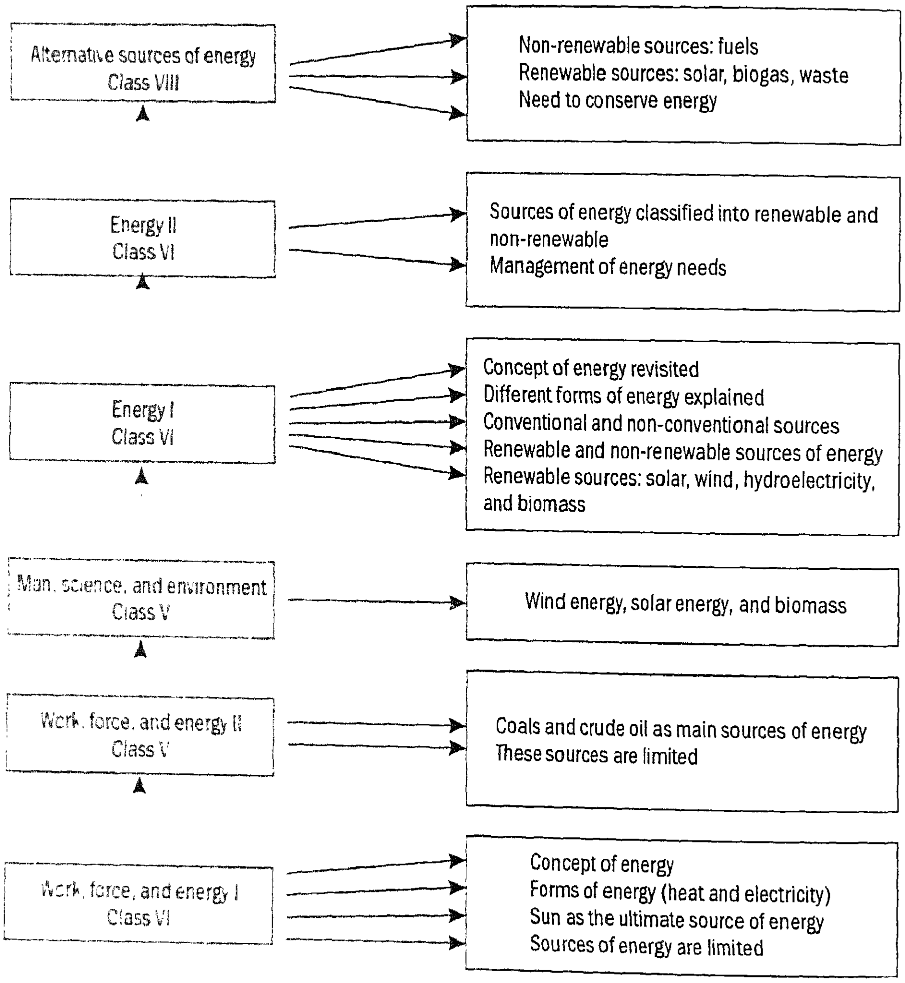

Alternative sources of energy
Class VIII
Non-renewable sources: fuels
Renewable sources: solar, biogas, waste
Need to conserve energy
Energy II
Class VI
Sources of energy classified into renewable and non-renewable
Management of energy needs
Energy I
Class VI
Concept of energy revisited
Different forms of energy explained
Conventional and non-conventional sources
Renewable and non-renewable sources of energy
Renewable sources: solar, wind, hydroelectricity, and biomass
Man, science, and environment
Class V
Wind energy, solar energy, and biomass
Work, force, and energy II
Class V
Coals and crude oil as main sources of energy
These sources are limited
Work, force, and energy I
Class VI
Concept of energy
Forms of energy (heat and electricity)
Sun as the ultimate source of energy
Sources of energy are limited

Figure 1 Development of the concept of energy through various stages of elementary education

Secondary level

The importance attached to teaching about energy at the secondary level can be judged from the fact that in class X, the first three chapters focus on energy. The first chapter talks about man, energy, and the relation between the two. Then it discusses how heat, a particular form of energy, is used in engines. The second chapter is on fuels wherein classification and characteristics of fuels are touched upon and biomass as a fuel is discussed in detail. The third chapter talks about the sun as the ultimate source of energy. A separate chapter discusses methods of harnessing solar energy in detail. Here, students learn about solar heating devices and solar cells. The science and technology of wind energy, hydroelectric energy, and energy from the oceans are also discussed at length.

Senior secondary level

At the +2 stage of science education, renewable sources of energy and methods to harness them are given adequate attention. There is a separate chapter on energetics (class XI chemistry) in which an entire section is devoted to sources of energy. In this section, it is once again emphasized that the sun is the primary energy source (Figure 2). Students learn that even photosynthesis is a potential process of converting solar energy into chemical energy. This chapter provides a comprehensive picture of various forms of energy with special mention of hydroelectric energy, energy from wind, and ocean waves. *Gobar* (cow dung) gas has been introduced as a source of energy in the rural areas. The potential energy of water in a dam is used to run turbines to generate electricity, and in this connection, hydroelectric power stations are mentioned. Wind, tidal waves, ocean currents, hot gases, and hot streams that rush out of the earth's interior in the form of geysers, hot springs, etc. (known as geothermal energy) are other renewable sources of energy which are yet to be exploited. At this stage, students realize that nuclear fusion, if conducted in a

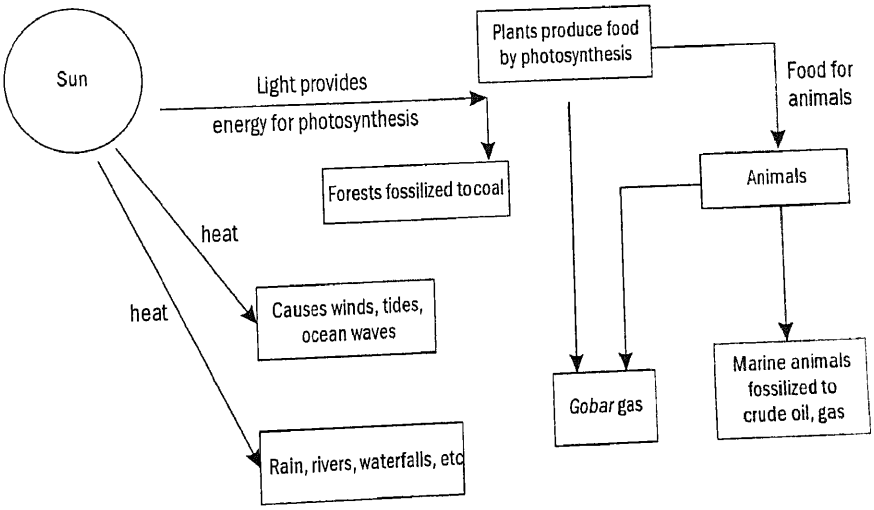

Sun
Light provides
energy for photosynthesis
Plants produce food by photosynthesis
Food for animals
Forests fossilized to coal
Animals
heat
heat
Causes winds, tides, ocean waves
Rain, rivers, waterfalls, etc
Gobar gas
Marine animals fossilized to crude oil, gas

Figure 2 Sun as the primary source of energy

controlled manner, can solve the world's problem of energy and that will be a renewable source since hydrogen, the prime source, is available easily. Special mention has been made of India's efforts in harnessing these sources of RE. Students are also taught the various practical ways to conserve energy in their daily lives. The need for the use of RE is emphazied in yet another way. Students learn about environment pollution associated with the use of conventional sources of energy and appreciate the use of RE sources.

The senior secondary curriculum covers not only the most common renewable sources of energy but also introduces the concept of 'hydrogen energy' as a future fuel. It is mentioned that a day will come when hydrogen could be supplied through pipelines for domestic use. Chemistry textbooks at the senior secondary level have even highlighted the research being conducted in the field of hydrogen energy. It is a well-accepted fact that hydrogen molecules which have high potential energy in the form of bond energy, will provide high calorific value as fuel free from pollution. Efforts are being made to split up water (having tremendous potential for hydrogen on earth) into hydrogen and oxygen. Through boxed material, the textbook explains how breaking of water into hydrogen and oxygen can be achieved using a photoelectric cell. In this context, the use of semiconductor (n- or p- type) photoelectrodes is mentioned. The book also provides detailed information about photochemical decomposition of water. Chemical conversion of solar energy can also be achieved by photochemical reactions occurring in homogeneous or colloidal solutions. The reaction requires a sensitizer because water itself does not radiate above 200 mm. Transition metal complexes are useful as sensitizers for this reaction. One can see that textbooks start from simple concepts of RE at the primary level and go up to the latest developments in the field of RE at the senior secondary level.

At the senior secondary stage, there is special mention of the *efficient use of energy*. It is in this context that a fuel cell is described, as it consumes fuel most efficiently in a electrochemical reaction. The concept of free energy, G, which is the maximum energy available for useful work, is introduced at this stage. The discussion is not confined only to mechanical devices for converting the free energy into useful work, but also takes into account the efficiency of biological systems. The conceptual level of the students is high enough to appreciate the concept of efficiency of consuming energy and the concept of energy crisis. Scientists and technologists believe that increasing efficiency is an indirect way of increasing energy resources.

Non-formal mode

Out-of-school activities form an important aspect of the non-formal mode of REE. In this direction, the NCERT (National Council of Educational Research and Training) has made concerted efforts to create awareness among school students about RE. The NCERT has been organizing the annual JNNSEC (Jawaharlal Nehru National Science Exhibition for Children) since 1971 for providing strength and support to the national movement of creating a scientific and technically literate workforce and capable human resources. Actually, the JNNSEC is a culmination of the state-level science exhibitions organized in the previous year on the same theme. Table 1 lists the themes and sub-themes of JNNSEC held in the last 10 years. It is clear that one of the sub-themes that finds a regular place in the JNNSEC is energy.

Table 1 Themes and sub-themes of the JNNSEC held during 1986-1997

Year	Theme	Sub-theme
1986	Science and the home	Energ-saving devices
1989	Science and man	Harnessing energy
1990	Nehru and science	Energy
1992	Science in A D 2001	The energy scenario
1993	Science and technology for national development	Energy
1994	Science and conservation of natural resources	Energy
1996	Science and low cost technology for development	Energy
1997	Science and technology for quality of life	Energy

If one goes through the lists of exhibits prepared by students, one notes that, over the years, the focus is shifting to the science and technology of harnessing RE sources. Apart from district-, state-, and national-level science exhibitions, there are other out-of-school activities to promote REE among students. Starting from the primary stage to the senior secondary stage, students take up project work as SUPW (socially useful productive work)or as part of their practical course. Students learn to design and develop solar cookers, solar heaters, etc. The NCERT has made special efforts to propagate the education of RE by publishing a book on solar energy under the project 'Reading to learn'. This is the first book developed on RE and is priced low.

Strategies to promote renewable energy education

It is evident from the above discussion that education on energy, in general, and RE, in particular, has been given due attention at different levels of school education. But a critical analysis of the content covered and the approach adopted shows that adequate attention has not been given to attempts made to harness RE sources in our country. Therefore, it is suggested that wherever possible, efforts should be made to educate students about the latest Indian scenario of RE.

Further, it is found that the study of the efficient use of energy is rather neglected in school science. Therefore, we have to develop an approach to the teaching of energy, which, even when it does not necessarily go beyond the conventional boundaries of a science course, does help our students to better understand some of the socially-related sciences. In fact, we should have a school-based programme that provides effective, across the curriculum, REE. It is high time we designed and developed such a curriculum package for school children.

In the age of information technology, it is only appropriate to create a web site which not only talks about RE at national and international levels but also encourages students to design models to harness RE sources. The web site should also provide a channel to students to interact with scientists and technologists working in the field of RE.

REE can also be promoted through newsletters, brochures, and workshops for students and teachers at the district, state, and national levels. Modules may also be designed to teach energy generation, conversion, and utilization by using self-directed, self-paced table-top activities.

Department of
Applied Physics
and Electronics
University of
Bangladesh
Dhaka
Bangladesh

S Rafique*, R R Khan, Md I Jabiullah

Renewable energy education and research programme in postgraduate level curricula: a case study and analysis

Renewable energy education: current scenario and future projections
pp. 307-312

Abstract

A renewable energy education and research programme has been designed and developed to be adopted at the postgraduate level in the universities of Bangladesh. Earlier, solar radiation spectra were recorded at various geographical locations of the country over a period of 10 years and these helped to establish the potential of solar power. Based on the survey studies, research activities, and practical needs, specific fields of renewable energy to be included in higher education, research, and training programmes were identified. They are solar thermal conversion, solar collectors, solar PV (photovoltaic) energy conversion, power conditioning of PV systems, and design of PV systems. The main objective is to teach students the fundamental principles of renewable energy for utilization in the rural areas. A solar spectrum for a period of 10 years (1988–1998) was also analysed to visualize the seasonal variation, cyclical variation, irregular variation, and future trends. In response to the trend, and realizing that solar power is an integral part of our daily life, it is suggested that renewable energy courses should be made an integral part of our entire education system – in schools, high schools, undergraduate courses, and higher level programmes.

---

* Author for correspondence

Introduction

Bangladesh is a country of about 120 million people and covers an area of 147 570 km^2. It is considered one of the most densely populated and high sunshine regions in the world. The country receives strong solar radiation throughout the year. It has 64 districts and 460 sub-district units. The capital is Dhaka and 80% of the country's population resides in the rural areas, devoid of modern amenities like electricity and pure drinking water. Out of 21 million households of the country, only 15% have been brought under the grid electrical network. Since the rural network is characterized by a comparatively lower consumer density, it often becomes difficult and uneconomical to extend grid-lines to certain locations even within the command areas of rural societies. Moreover, some remote areas cannot be covered by the network due to inaccessibility and low demand density. As a sun-bright country, there is immense scope and potential for the use of SPV (solar photovoltaic) technology in these areas. It is also believed to be a viable technical option for such areas, especially for ensuring equitable development of all areas and socio-economic strata.

Recognizing the importance of SPV technology in Bangladesh, the Government has been designing a comprehensive programme. The programme includes education, research, training, and development with special emphasis on the participation of the younger generation in SPV technology. Accordingly, a curriculum has been designed for the fourth year students of the Applied Physics and Electronics Department of Dhaka University. The curriculum includes solar thermal conversion, solar collectors, solar PV energy conversion, power conditioning of PV systems, and design of PV systems. The project includes design and fabrication of solar panels and design of ballast, charge controller, inverter, and maximum power point tracker. This paper presents the detailed syllabus for solar energy technology and an analysis of the solar data obtained continuously for the last decade.

Syllabus for solar energy technology

The entire course is divided into five distinct categories.

Solar thermal conversion

This includes heat transfer – modes of heat transfer, radiation laws, radiative heat transfer coefficient, heat transfer coefficient of natural and selective surfaces, forced conversion, and radiation characteristics of materials, e.g., absorptance, emittance, and reflectance.

Solar collectors This category comprises flat-plate collectors, concentrating collectors, solar distillation, solar energy systems for process heating, power generation and refrigeration, performance and optimum design, and solar thermal modelling.

Solar photovoltaic energy conversion This includes the general principle and types of solar cells, p–n junction as PV cell, heterojunctions, Schottky barrier junctions, solar cells in series, in parallel, and in combination in different forms and effect of shading, anti-reflection coating and texured cells, thin film solar cells, multiple sun solar cells, PV systems, arrays, modules, and panels, dimension of cells, and packing efficiency of cells in modules.

Power conditioning of photovoltaic systems This contains batteries, inverters, maximum power trackers, energy systems without battery, energy storage in battery, PV grid interconnection with battery storage, and energy storage system with diesel back-up and battery storage.

Design of photovoltaic systems This includes calculations of array size and battery capacity and selection of array modules.

Research activities related to present projects

- Design and development of a microprocessor-based solar energy recording to be used in SPV systems. The paper was published in the journal *Role of Renewable Energy in Energy Policies*, New Delhi, India, 1994.
- Development of a solar energy plant for rural application (supported by Science and Technology Ministry under the scheme of R&D project 1991–92). This paper has been presented and published in the Third World Academy of Science's international conference: *Women's vision of science and technology for development.* The specific topic under which this paper was presented was *Use of natural resources and their enviromental impacts.*
- Fabrication of PV panels and their application in PV systems. This work includes the development of a simple low-cost fabrication process of PV panels. The Science and Technology Ministry under R&D fellowship (project 1992–93) supported this project.

Analysis of solar radiation

A statistical inquiry of the solar radiation in SPV has been done and data has been collected from 1988 to 1998 by the Institute of Science and Technology, Bangladesh. Next, two broad areas of classical statistics have been applied for this purpose. The first is descriptive statistics utilizing numerical and graphical methods to look for patterns to summarize and present the information in a set of data. The second is inferential statistics utilizing the sample data to make estimates, decisions, predictions, and other generalizations about the entire population.

The set of solar data recorded continuously from 1988–1998 is shown in Table 1. The graph plotted with the time series is shown in Figure 1.

Table 1 Long-term (1988-98) average isolation (kWh/m^2) measured at six locations in Bangladesh

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessore
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97

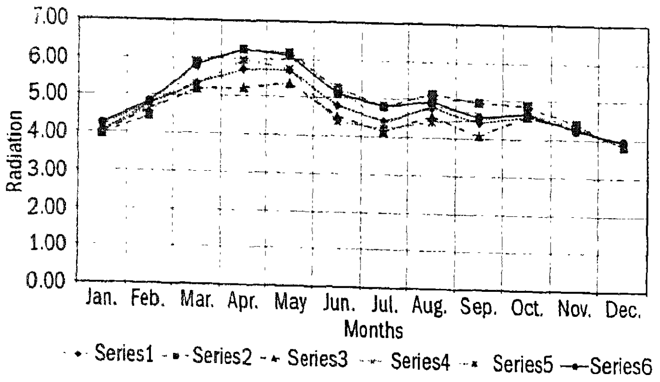


Figure 1 Solar radiation in Bangladesh

The graph shows the general movement persisting over a period of 12 months. If we examine the curve, we can see that for each district the curve starts with a low figure in January and reaches a peak in the early middle part of the year in April–May and then decreases again at the end of the year. The end point is almost the same as the start point.

Next, the least square method has been applied for the radiation data as shown in Figure 2.

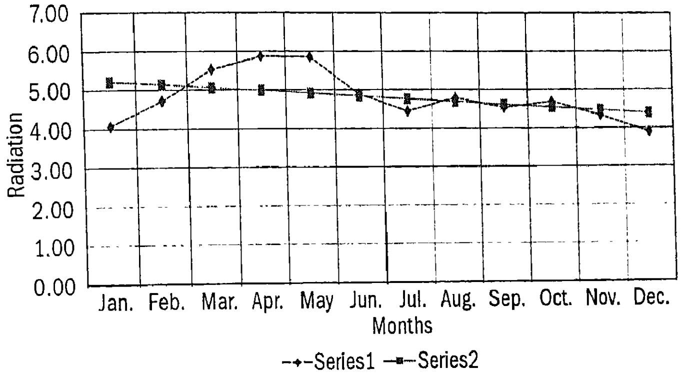


Figure 2 Linear trend by the method of least squares

When this method is applied, a trend line is fitted to the data in such a manner that the following two conditions are satisfied: (i) $\Sigma(Y-Y_c) = 0$, i.e., the sum of deviations of actual values of Y and computed values of Y_c is zero, and (ii) $\Sigma(Y-Y_c)^2$ is least, i.e., the sum of squares of deviations of actual and computed values is least from this line. That is why this method is called the method of least squares. The line obtained by this method is known as the line of best fit.

Table 2 shows the average radiation Y in all the districts over the year. The deviation from June is listed in column 3. Column 4 shows the X^2 values. Finally, the trend values are listed in column 6. These are computed values.

The equation of the straight line trend is $Y_c = a+bx$. Since ΣX is not zero, we have to solve the two normal equations simultaneously.

$$\Sigma Y = Na + b\Sigma X \qquad \dots (1)$$

$$\Sigma XY = a\Sigma X + b\Sigma X^2 \qquad \dots (2)$$

From Table 2, we get the values of ΣX, ΣXY, and ΣX^2. Substituting these values in (1) and (2) we get a = 4.838, where a is the Y intercept or the value of the Y variable and b = 0.075, where b is the slope of the line or the amount of change in Y variable for the radiation data.

Now substituting the value of a and b in equation $Y_c = a + bX$, the trend values have been obtained and the graph of the above data is given in Figure 2. Fast Fourier Transform of the

Table 2 Fitting straight line by the method of least squares

Month	Average radiation Y	Deviation X	X^2	XY	Trend Y_c
January	4.07	−5	25	−20.35	5.21
February	4.71	−4	16	−18.84	5.14
March	5.53	−3	9	−16.59	5.06
April	5.87	−2	4	−11.74	4.99
May	5.85	−1	1	−5.85	4.91
June	4.89	0	0	0	4.84
July	4.45	1	1	4.45	4.76
August	4.79	2	4	9.58	4.69
September	4.53	3	9	13.59	4.61
October	4.69	4	16	18.76	4.54
November	4.33	5	25	21.65	4.46
December	4.98	6	36	29.88	4.39
N=12	$\Sigma Y=57.61$	$\Sigma X=6$	$\Sigma X^2=146$	$\Sigma XY=18.06$	$\Sigma Y_c=57.61$

original data has been done and energy spectral densities obtained.

Conclusion

The time series analysis has greater significance for SPV system development. The radiation over a period of time shows the change in energy and is extremely helpful in the prediction of the pattern in future. If the feature and regularity of pattern over a sufficiently long period (say 20 years) could be clearly established, then, the prediction of future variations can be possible within certain limits. This is extremely important for planning the energy policy of Bangladesh.

The main objective has been to design appropriate curricula incorporating fundamental laws of solar energy for education, training, research, and implementation. The designed syllabus should hopefully fulfill these requirements. From the various analyses, it has been realized that solar power is an integral part of our daily lives, so solar energy education must be integrated in our primary, secondary, higher secondary, undergraduate and postgraduate study programmes.

School of Energy
and Environment,
Devi Ahilya
University,
Khandwa Road
Indore - 352 001
India

R L Sawhney*, Atam Kumar

Solar water heating systems for training and demonstration in postgraduate programmes

Renewable energy education: current scenario and future projections
pp. 313-332

Abstract

Most of the solar laboratory experiments developed for postgraduate programmes in the country deal with performance studies of solar collectors and their components. Six laboratory experimental units incorporating essential components and features of different type of solar flat plate collector water heating systems have been designed, fabricated, and installed. Three of the units are based on thermosyphonic flow systems, two on forced flow systems, and one on the gravity flow system. Systems are also provided with various combinations of series and parallel connections of the collectors, auxiliary heaters of different types, heat exchangers of two types, and different control mechanisms.

Alcohol thermometers and rotameters are provided at appropriate places for temperature and flow measurements. The units are being used as laboratory experiments of the M. Tech. (Energy Management) programme as well as demonstration units for the public and training units for prospective technicians.

---

* Author for correspondence

Introduction

The MNES (Ministry of Non-conventional Energy Sources), Government of India, sponsored a project *Performance Evaluation of Industrial/Commercial Solar Water Heating Systems Installed in the State of Madhya Pradesh and Evolution of Suitable Implementing Strategies.* Out of 354 industrial/commercial systems (capacity >500 litres per day) of total capacity 1.555 MLPD (million litres per day) installed in the state, 162 systems (capacity 0.767 MLPD) were inspected by technical team. Of these 162 systems, 64 systems (capacity 0.508 MLPD) were evaluated by an expert group. 43 systems (capacity 0.518 MLPD) were found to be either under-utilized or not functioning though their collectors were in good condition.

The main reasons for non-functional systems were:

- design-related problems;
- non-availability of trained manpower for repairing the system; and
- casual attitude of the user.

Other reasons for poor functionality of the systems or non-utilization of their full capacity include:

- oversizing of the system;
- poor system design; and
- improper installation.

Problems related to the design, installation, and maintenance affecting the performance and proper functioning of the systems along with their suggested remedies are listed here.

Components

Collectors

Observations

- Sagging of loose glass wool insulation during transportation, installation, and over the period of use of collectors was common.
- In some cases, it was observed that bonding of risers with absorber was of these types:
  - Soldering of 5 cm length after a gap of 5 cm
  - Soldering of 2 cm length after a gap of 10 cm
  - Spot welding at interval of 5 cm
- Collector quality in general was found to be very good. Wherever galvanized iron boxes were used, rusting of the boxes after four to five years was common. The collectors with aluminum boxes in certain cases even after seven to eight years of their use/disuse were found to be in good condition.
- The corrosion in the form of greening of risers at riser–header joints was most common.

Suggestions

- Sagging of insulation can be avoided by using padded insulation and fixing it with adhesive applied at the back of the box.
- Soldering of absorber plates to the risers should be all along the risers on both sides. Poor bonding not only reduces the collection efficiency, but also increases the chances of absorber plate being desoldered from the risers and sleeping down in case it is made of sheets of copper plates.
- Stoving paint with specification to withstand 200 °C with matt finish should be used in painting the headers and absorber plate. Blackboard paint should not be used, as it starts scaling.
- The flux should be removed from the brazed joints, otherwise the chloride present in flux, combining with copper forms cuprous chloride thereby corroding the copper.
- For the absorber, stoving (etch) primer should be preferred in place of the red oxide primer.
- Generally absorber plates are not attacked by external corrosion but scales are common.

Tanks **Observations**

- In many cases, the drain point was not provided separately at the bottom of the tank but in other pipelines connected to the bottom of the tanks. In this arrangement, it will not be possible to remove dust and dirt from the tank as the pipe mouth inside the tank is kept little above the tank bottom.
- In a larger number of cases, the insulation provided was adequate (10 cm loose and 8 cm padded), while in some cases it was merely 5 cm. In very few cases, even 5 cm insulation was not provided.
- Tank insulation in general was found to be well-cladded. In some cases, it was found that water had leaked into the insulation.
- Most of the hot water tanks were cylindrical. Leakages were more common in rectangular tanks than in cylindrical tanks.
- In most of the tanks which could be opened for inspection, dust and rust was found accumulated at the bottom.
- In cases where the cold water tank was at a much higher level than the system, simple pipe air vents provided in the system (generally in hot water tanks) were at a height equal to the cold water tank height (otherwise water

would overflow through this vent).

- In almost all the cases, MS (mild steel) tanks were found rusted from inside. Either they were not properly polyurethane-painted or the paint applied was poor.
- In a few cases, tank insulation was not covered with polythene film before cladding.

Suggestions

- Losses from the tank occur all 24 hours but are larger during the night than during the day. In collectors, losses occur during the collection period, when the ambient temperature is also high. Hence, proper insulation of tank is much more important. For the tank, 10 cm insulation of padded glass wool is recommended.
- For a given requirement of hot water, though the collector and cold water tank size are independent of the demand pattern, the hot water tank size critically depends on the demand pattern. The larger the off-day time requirement, larger will be the size of the hot water storage tank. Cold water storage tank size should be equal to daily requirement.
- Tanks should be cylindrical as far as possible as there are more chances of leakages in rectangular tanks.
- In a thermosyphon system, the cylindrical tanks should be kept vertical for better stratification.
- In forced-flow systems, tanks may be kept horizontal (as the chances of rainwater seepage into the insulation in horizontal tanks are less than in vertical tanks).
- To avoid short-circuiting as far as possible, the inlet and outlet points of hot water should be on the opposite sides of the tank.
- A separate drain point should be provided in the tank with its mouth in level with the tank bottom so that rust and scale can also be removed through it.
- All other pipes connected to the bottom of the tank in the system lines (except the drain point) should enter the tank a little higher than the tank bottom to avoid the entrance of dust and dirt into the system.
- If the cold water tank is at a much higher level than the system, a separate make-up tank with float valve should be provided at lower heights. This will reduce the pressure on the collectors and also the required height of simple pipe air vent provided in the system.
- In thermosyphon systems, the cold water inlet in hot water tank should be as far as possible through a diffuser or through a pipe in the tank with the holes drilled on the

bottom side of the pipe. This is to promote stratification and avoid mixing. The holes drilled in the pipe should be sufficient in size and number, so that total cross-sectional area of the combined holes is larger than the cross-sectional area of the inlet pipe. This is to reduce entrance velocity and hence chances of mixing.

- The user line from the hot water tank should always emanate near the top edge of the tank in the water displacement type system and from the bottom of the tank in the water non-displacement type system.
- In the thermosyphon system, the user line should be taken out from the top of the tank instead of the middle as was observed in certain cases.
- Whenever hot water tanks of different systems are connected in parallel, the connection of the supply lines has to be balanced very carefully, otherwise, the hot water drawn from each tank may not be the equal thereby reducing the usefulness of the system which is contributing lesser amount of hot water to the total requirement.
- As far as possible, the location of the hot water tank in relation to the collectors should be such that the length of hot water piping is minimum.
- In vertical hot water tanks with large capacity, a manhole should be provided in large tanks for easy cleaning and should be insulated and cladded properly to avoid losses and rainwater entry.
- In case of MS tanks, it should be ensured that they are properly polyurethane-painted.
- Insulation should be covered with polythene film before cladding to protect it from the rainwater.

Pipes and fittings

Observations

- In certain cases, for systems of 1000 litres per day and 5000 litres per day, the pipe connecting the outlet of the collector to the hot water tanks was observed to be 0.75 inches in diameter. This results in higher velocity and turbulence in the tank causing mixing.
- The flow meters installed were generally not functioning because of the rusting of the float and deposit of rust coming from other parts of the system.

Suggestions

- In thermosyphon flow systems for 2000 litres per day, pipe diameter of cold water line should be 1.5 inches and for 3000 litre per day systems, it should be 2 inches.

- As far as possible, ball valves should be used in place of gate valves, because in ball valves the state of the valve (opened/closed) is easily identified.
- A gate valve should also be provided in the cold water line from cold water tank to collectors/hot water tank otherwise when the collectors are drained, water from the cold water tank would also get drained.
- In small capacity thermosyphon systems, it is essential to ensure that the line from the collector output to the hot water tank always slopes upwards.
- Only when good quality rotameteres are available, they should be used for balancing the flow in each row.
- In the single-pass forced-flow system, a solenoid valve should be provided before the pump otherwise pressure of the system will run the impeller of the pump in reverse direction. This also helps in keeping the pump primed.
- Air vents should be provided at the highest and the hottest point in the flow line.
- For a larger system, each collector row should be provided with globe/gate valves on both sides of the row so that each row can be isolated for repairs whenever it is required.
- At the collector outlet, in place of an air vent, air separators can be provided for instant air release and eliminating wastage of hot water during air release.
- In the multipass force-flow system, a non-return valve should generally be provided in the collector return line to prevent reverse flow in the night. A solenoid ball valve, which opens only when the pump is on, can also be used for preventing night reverse flow.

Controls and sensors

Observations

- In a large number of cases, sensor-based controls were not functioning.
- In some cases, the user had made innovations in the system design when the original design gave problems.
- The spring loaded relief valves get jammed unless periodically operated.

Suggestions

- The use of sophisticated controls in small systems should be avoided, especially when the user does not understand them completely.
- In fixed temperature forced-flow systems, motors with intermittent ratings (heavy duty) should be used instead of motors with continuous rating. For fixed flow systems, motors with continuous ratings should be used.

- A liquid level controller should be used in the single-pass system to prevent the overflow of hot water storage tank.
  - In a fixed-flow system, if the solenoid valve is used, it should be controlled by liquid level controller.
  - In fixed temperature systems, the liquid level controller should be used to override the operation of the thermostat, which controls a pump and a solenoid valve.

Pumps

Observations

- In one of the systems, water was found to be leaking profusely from the joints because of the large pressure head pump installed although the system was still in use.
- In some cases, cold water pumps were used in hot water lines.
- The pumps are generally selected on the basis of their horsepower ratings instead of the required flow rates and pressure heads.

Suggestions

- In the hot water supply line, pumps capable of working at higher temperature with gasket material which can sustain higher temperature should be used.
- Pumps should be selected for a required head and flow rate, but it is not always feasible. In such cases, the next available higher rating pump should be selected.
- As low pressure high discharge pumps are generally not available, series–parallel distribution of collector in an array should be such that net pressure head and flow in the system corresponds to the available pump in the market.

Heat exchangers

Suggestions

- While designing the heat exchangers in thermosyphon systems, it should be remembered that the flow rate in the collector circuit is very low (i.e. heat transfer would be very low) requiring higher heat exchanger surface area compared to the forced-flow system.
- In the case of systems with heat exchangers, the makeup-expansion tank should be connected on the suction side of the pump. Otherwise the height of the tank may have to be substantially increased to avoid overflowing. No non-return valve must be installed in the line connecting the make-up tank with the system. Installation of a non-return valve results in overpressurizing the system.
- In tube–tube heat exchangers, hard water should pass through the inner tube. With this arrangement, the flow

rate inside the inner tubes can be made as high as possible (as this will not pass through the collector circuit). The large flow rate also reduces the chance of scale deposits. Moreover, the cleaning of inner tubes is easier.

- MS heat exchanger (coil or cage type) can not withstand descaling efforts. MS heat exchanger in SS (Stainless steel) tank also increases the chances of corrosion of MS. Hence, in coil or cage type heat exchangers SS coil/cage in SS tank should be used.
- In thermosyphon system for very small head, only cage type heat exchanger in a shell (hot water tank) is recommended as the resistance offered by cage geometry will be very small. A cylindrical shell heat exchanger in which water of the collector circuit flows in the outer shell can also be used.
- In forced-flow system, the heat exchanger can be of coil type for smaller systems or tube-in-tube type for larger systems. But in this case, because of the lower velocities, the heat transfer will be poor and the required insulation of the tank will be larger.

Electrical backup

Suggestions

- Hotels and guest houses with large number of rooms have large distribution pipelines and hence large dead storage. The water in pipelines are likely to get cold. Hence where instant hot water is desirable, in addition to the supply line from the tank, a return line from the supply line to the hot water tank should be provided, so that before supplying the hot water in the line can be heated up by circulating it through the hot water tank with the help of a circulating pump provided in the line.
- Auxiliary sources controlled by thermostats can be installed in the solar hot water tank or outside the solar hot water tank.
    - In the hot water tank it should be installed near the top of the tank as this will promote the stratification in the tank. However, as the heat is being added to the tank, average temperature of the tank will increase resulting in increased collector inlet temperature and reduced collector efficiency.
    - Auxiliary heat can be added outside the solar hot water tank as a simple line heater connected in series or parallel to the tank or electrical geysers with its own storage capacity connected in series or parallel to the tank.
    - Both the methods (series or parallel connection) have the advantage that they do not affect the solar hot

water tank temperature and hence collector circuit performance. But a conventional heater with its own storage capacity has the disadvantage of additional heat loss from the conventional heater surface. In case the auxiliary heat source is connected in parallel with the solar hot water tank it is switched on whenever the temperature in the hot water tank is below the set point temperature.

Design aspects

Suggestions

- For higher efficiency of the system, it should be designed for lowest possible average operating temperature of the collector arrays.
- In systems with non-uniform flow distribution, chances of air locking increase because of high temperature achieved in rows with low flow rates. Hence, the system should be designed a manner that the flow rate in each row is such that the outlet water temperature from each row is equal as far as possible i.e. flow rate in a row should be proportional to number of collectors in the row.
- Large systems will have large dead storage. For a 5000 litres per day system, the dead storage (in collectors and pipelines) will be approximately 300 litres.
- Lower flow velocities will increase chances of scale formation and also of air locking (due to high temperature achieved). Also it should be remembered that for low flow velocities, connective heat transfer coefficient have smaller value.
- In the mornings (7 a.m. to 8 a.m.) and evenings (4 p.m. to 6 p.m.), the solar radiation is almost at grazing angles on the collectors leading to low transmitivity. Therefore while designing the system, the collection period should be considered between 9 a.m. and 4 p.m.
- Array distribution should be as symmetrical as possible along with equal flow paths in the piping to ensure uniform flow in all the collectors. The number of collectors in different arrays should be as equal as possible. If not, efficiencies will be different in different arrays, i.e., less in array with large number of collectors and high in array with less number of collectors.
- In the thermosyphon system, as far as possible, the collector should not be connected in series. In parallel connection, not more than five collectors should be connected in one bank as flow distribution in the collectors become non-uniform. In a collector array of more than five collectors (say 10), a bank of five collectors may

be connected parallel to another bank of five collectors.

- In a forced-flow system, not more than 10 collectors may be connected in series. As low pressure head high discharge pumps are generally not available, series–parallel distribution of collectors should be planned that head and flow requirements match with pumps available in the market.
- The tilt separation between the collectors was not as per the requirement of the latitude of the place.

Installation aspects

Collector base support

Observations

For the bottom support of the collector, the different arrangements used were as follows:

- Collector directly placed on *pucca* floor, without any base support
- Collector directly placed on *pucca* roof/floor without any base support but with one brick layer constructed in front of the bottom of the collector
- Collector placed on roof/floor supported by ordinary brick pieces or brick pillars
- Collector placed on *pucca* roof/floor with V-groove rubber block
- Collector placed on common angle iron placed on V-groove rubber pads
- Collector placed on common angle iron (horizontal) welded to a vertical flat strip which is grouted to the roof/ floor
- Collector placed on common angle iron welded to the another vertical angle iron grouted in the ground
- Vertical angle iron directly welded to the MS box of the collector and buried in the ground
- Angle iron pieces fastened to the collector box at its two ends and angle irons of two adjacent collectors slipped into slots of single angle iron hinged to another angle iron grouted into the ground or floor
- Beams raised on pile foundations wherever the grounds were marshy or of black cotton soil
- Collector array clamped to a frame of angle iron and the vertical angle iron supports welded to bottom and top end of the angle iron frame and grouted to the roof/ ground
- Collector bottom resting on angle iron piece welded to a vertical angle iron piece which is grouted to the brick support
- Collector resting on a horizontal angle iron has problem of trapped rainwater between the collector and angle iron which accelerates the corrosion of the collector box

Suggestions

- The placement of the collectors directly on the concrete/paved ground/floor against brick walls is not recommended because:
  - water is likely to collect near the bottom edge of the collector thereby increasing chances of its corrosion, and
  - dust is also likely to accumulate between the brick wall, floor, and collectors thereby increasing the chances of growth of vegetation.
- It is recommended that collectors of GI (galvanized iron) box should use bottom clamping arrangements while collectors of aluminium box should use top and bottom clamping arrangement.
- Small holes should be drilled at the edge of the lower horizontal angle iron supporting the collector (at least four per metre), so that rainwater does not get trapped.
- It is felt that the two U-clamps on one collector at the distance of one-third of the collector width should be used instead of only one U-clamp per collector.

Collector top support

Observations

For the back supports of the collectors, different arrangements used were as follows:

- Collectors supported on a wall and held by a wire buried in to the wall
- Collector placed on angle iron frame of a size of about two-thirds of the collector length, two collectors and clamped to the upper horizontal arm of the angle iron frame, end of the outer most collector left unclamped
- Two collectors placed on a single frame of angle iron and welded to a vertical GI pipe grouted to the floor
- Individual collector supported at the two ends with hinged type angle iron support
- A set of two collectors placed on angle iron frame and supported by vertical angle iron at two ends of the set of two collectors
- Collectors blown off with the frame intact because of non-clamping of the collector to the frame
- Collector screwed to a horizontal angle iron piece which is welded to a vertical angle iron grouted to the floor/roof
- Jyoti Ltd had devised a reasonably good arrangement where the height of the back support could be adjusted. Most often, the same arrangement was also used for aluminium collectors which is not advisable. Because of lower shearing strength of the aluminium and because the entire weight of

the collector in this arrangement is supported at one point, it was observed that the aluminium box was compressed at the back particularly when the supporting unit was not fixed at the top edge of the collector.

Suggestions

- In certain cases, it was found that clamping at the top resulted in the tearing of aluminium sheet of the box due to high wind loads. Hence, with an aluminium box this arrangement is not recommended. In this arrangement collectors in one array are generally not aligned and may lead to the bending of the collectors at the two ends of the array.
- When a horizontal piece of angle iron welded to vertical angle iron is screwed at the edge of the collectors, no arrangement for the adjustment of the height of the vertical element is provided and hence, wherever required vertical angle iron is bent with the hammer to adjust the height. Screwing of angle iron with aluminium box is not advisable because due to wind jerks, the screwing may get loose.
- A set of two collectors placed on angle iron frame and supported by vertical angle iron at two ends of the set of two collectors, which are clamped to the frame, can be used for small numbers of collector array with vertical angle iron supports at the top and bottom given at the middle of each collector. We feel this is a good arrangement for the collector supports. This arrangement can be made modular with angle iron frame for two/three collectors.

Collector-to-collector joints

Observations

Various collector-to-collector joint mechanisms observed include:

- through hose pipe clamped to the headers,
- through flange joint: brass flange fixed to collector header and joined through a gasket,
- through GI union,
- flared collector copper pipe connected through brass union (as is generally done in tube joints in A C refrigeration systems)
- brass flanges with slots instead of holes

Suggestions

- Brass flanges with resin-bonded asbestos fibre gaskets are recommended.
- In the first and last collector of an array where the collector inlet and outlet copper flanges are to be connected

with the GI flanges of inlet and outlet pipes, the washers placed with the nut and bolt arrangements should be that of non-conducting material to avoid galvanic corrosion. (This isolates the two different metals electrically.)

- Flanges with holes should be preferred to slotted ones.
- All collector-to-collector fittings should be made of brass and not iron.
- Flared copper header pipe connected through brass union can be used. It is easy to disconnect collector joints at the time of repair and maintenance.

Tanks

Suggestion

- In thermosyphon systems, as far as possible, the bottom of the cold water tank should be just above the hot water tank. The bottom of the hot water tank should be above the collectors. The first would reduce the pressure in the system while the second will reduce the chances of reverse flow. If the bottom of the cold water tank is below the top of the hot water tank, the water height common to both the tanks will create dead weight, which is of no use.

Pipes and fittings

Observations

- At many places, it was observed that pressure equalizers in the hot water tank are used as air vents.
- Cladding and insulation of the pipelines laid on the ground or roof were found to be damaged by people stepping on them.
- Whenever cold water or user's hot water line is laid on the ground near cement/coal/dust, it is observed that these lines get buried under the coal/ash/cement dust making maintenance difficult.
- Pipelines without any vertical support were found in some cases. Sagging of the line in such cases may increase the chances of air locking if the system is a thermosyphon system.
- In some cases, the collector outlet from each row was connected to the main hot water line laid near the ground. This required the flow of hot water in a downward direction which promotes air locking.
- In some cases, it was found that the pipe length could have been reduced by almost 33% by using the shortest route.
- Support for the pipes was usually of brick column or angle iron or galvanized iron painted pipe.
- Wherever a hot water line is clamped to its vertical support, asbestos insulation is desirable between the clamp and pipe.

Suggestions

- Air release valves should be so installed that water coming out of the valves does not fall on any part of the system.
- For medium and larger capacity system, it is advisable to have air release valve in individual collector rows.
- Joints of valves and unions should be leakproof.
- Lines should be fixed to the walls or raised from the ground to a height of about of 2.5 inches or more so that people cannot sit or step on them.
- The height of the main hot water line should be equal to or above the collector output level to reduce air locking.
- Lines from the tank into the collectors in small thermosyphon systems can be laid under the collectors. This would protect the line from people walking on them and damaging the cladding and insulation.
- Circular pipe supports can also be used from outside the cladded line, but in this case, to avoid misshaping, a wooden piece can be used as separator between pipe and the cladding.
- The layout should be such that pipe length from one point to another point is minimum.
- The hot water line from the collectors to the hot water storage tank should always go up. If it goes downward, chances of air locking before the tank increase. This is very crucial for thermosyphon and gravity flow systems but may also be provided in forced flow systems. Air vents should be provided at the highest and hottest point in each collector array.

Controls and sensors

Observations

- In almost all the cases, the thermostat was initially put in a box to protect it from rain/dust. In most of the cases, the box was found missing.
- Proportional sensors were not used anywhere.
- Controllers generally used are :
  - flow controllers like solenoid valves, thermostatic controllers, and differential controllers (on/off and proportional)
  - level controllers like tank level controllers
  - pressure controllers like pressure release valves, and pressure controllers.

Suggestions

- In single-pass system, as far as possible a level controller should be installed. Wherever this is not possible, a tube level indicator (glass/acrylic) should be provided.

- Control panels may be located under the collector array or be attached to the collector back frame.
- The sensor bulb of thermostatic control or differential controller can be fixed on to the absorber plate in an array or it can be placed in a thermowell just next to the collector outlet. The first option is better, but needs collector opening for sensor replacement/repair. In the second option, when the water is not flowing, temperature in the thermowell will be lower than the temperature of the water in the collector.
- One of the sensors should be at the bottom of the hot water storage tank and the other on the collector plate near the outlet point of the collector or in a temperature well in the outlet pipe. In the first case, although the sensor is protected, it is difficult to repair or replace the sensor at this location. In the second case, as in no flow condition, the sensor is in stagnant water whose temperature will be lower than the collector plate temperature, and hence will require lower temperature differential setting than in the first case. In each case, whenever the plate temperature in no flow condition exceeds the tank bottom temperature by specific value T_{on} the pump is switched on. As soon as the pump is switched on, the temperature at the outlet decreases (because of energy withdrawal during the flow condition). This decrease will depend on the collector heat capacity and mass flow rate of the water. For larger heat capacity values of the collectors and smaller flow rates, decrease in temperature will be smaller. When the pump is on and the measured temperature differential falls below a specified amount T_{off} (due to fall in solar radiation level or increase in tank temperature), the controller switches off the pump. Care must be exercised when choosing T_{on} and T_{off} to avoid unstable conditions of 'on' and 'off'.

Site selection

Suggestions

- Water quality at the site should be tested before the installation of the system.
- Temporary water hardness where the system is to be installed should not be more than 200 ppm and permanent hardness should not increase more than 300 ppm.
- For water hardness of about 600 ppm, heat exchanger softener should be used.
- SPM (suspended particulate matter) in air should be measured and zones with fine dust should be avoided.

- System site should be away from the chimney, grinder for coal, pulverizer, and boiler.
- The cold water tank as well as user point should be kept close to the system as far as possible.
- To take advantage of albedo, system installed on a roof with large area (larger than required for collector installation) should be so installed that open space is in front of the collectors rather than behind the collector.

Maintenance aspects

Collectors

Observations

- The collector gasket for sealing the glass cover was found to be loosened and hanging out in quite a number of cases.
- Choking of collectors due to scaling was observed at many places.
- Sagging of the riser–header joints was also observed in most of the cases.
- Corrosion of the riser header joints was also observed.

Suggestions

- All desealing agents are acidic, and hence corrosive to the system. After descaling, the system should be neutralized with suitable solutions like sodium carbonate and flushed again with clean water.
- The corroded copper joints should be cleaned, brazed, and repainted.
- Cleaning of glass should be ensured regularly; its frequency can be decided as per the local environmental conditions. If the collector tilt angle is more, less dust will accumulate on it and hence reduce the need for glass cleaning.
- Aluminium boxes generally do not get corroded and last longer. MS boxes require regular painting and hence have a higher maintenance cost. Reinforced fibre glass is not found to be better than aluminium box.
- Scaling rate is higher at low velocity areas/regions. Scale deposit formation will generally start at the edges where velocity is less.
- The variation in the temperature of the glass cover of different collectors is an indication of the variable flow conditions in the collectors. For choked collectors or for non-flow conditions the temperature of the glass cover will be higher than that in the case of collectors with normal flow. Non-flow conditions can also occur either because of closed gate valves of the line or because of air locking of the line. For diagnosing a system for the non-

flow conditions, all the gate valves should be checked for their opened condition. Thereafter, all the air vents should be opened to release the locked air. If the glass cover temperature even after the above two operations is found to be higher this is most likely to be due to the choking of the collectors.

- During long shutdown periods, collectors should be covered. Excessive temperature change due to high stagnation temperature during the day and low stagnation temperature during the night for longer periods can cause severe outgassing problems, leakages in pipe coupling, cracked glasses, etc.

Pumps

Suggestion

- Where a standby pump is provided, both pumps should be used alternately. In most cases, it was found that only one pump was being used regularly leading to jamming of the other unused pump.

Experimental/ demonstration units

Based on the observations and suggestions emanating from the above exercise, it was decided that some solar water heating systems incorporating the most essential features and avoiding the pitfalls of the system design should be developed, designed, and installed. Under another project sponsored by MNES, six solar water heating systems were developed, fabricated, and installed at SEES (School of Energy and Environmental Studies), Devi Ahilya University, Indore.

Each unit has 10 collectors (2 × 1 ft^2) with hot water tank capacity of 100 litres per day. All possible combinations of series–parallel connection of flat plate collectors, different types of heat exchangers, auxiliary heaters, and their location, control systems and flow types (thermosyphon, flow, forced flowed gravity flow). For temperature measurement, glass thermometers were provided at appropriate points in the system. The six systems are given in Figures 1–6.

The units were mainly designed as laboratory experimental units of the solar thermal laboratory of the M.Tech. (Energy Management) programme. The units are also being used for training designers/technicians and giving demonstrations to college/school children and the public at large.

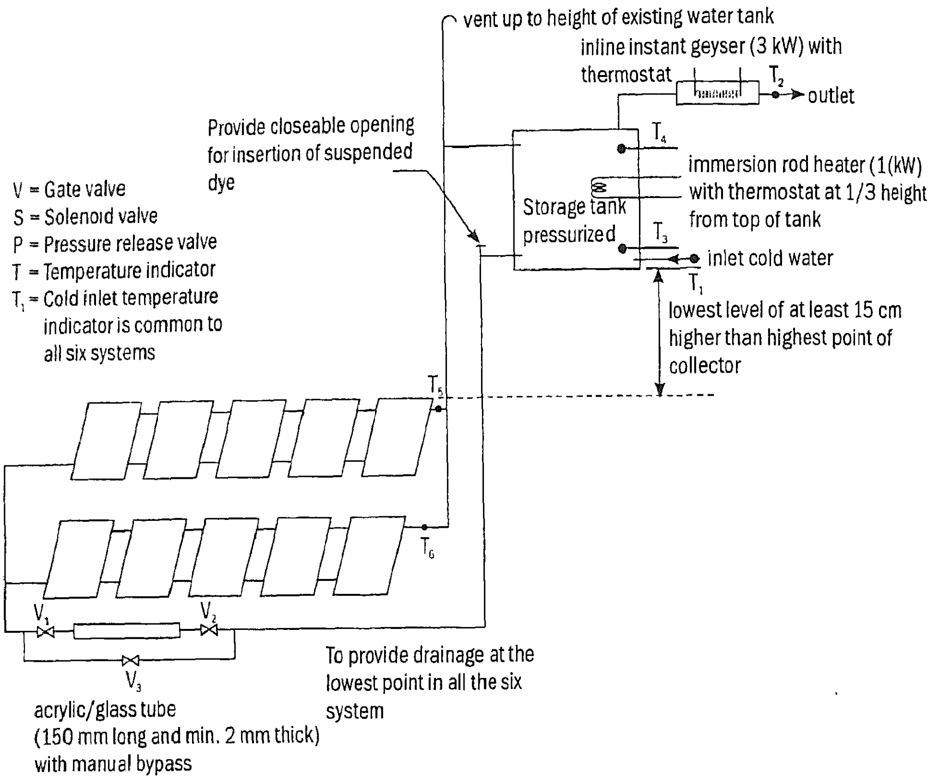

vent up to height of existing water tank
inline instant geyser (3 kW) with thermostat
T_2
outlet
Provide closeable opening for insertion of suspended dye
T_4
immersion rod heater (1(kW) with thermostat at 1/3 height from top of tank
Storage tank pressurized
T_3
inlet cold water
T_1
lowest level of at least 15 cm higher than highest point of collector
V = Gate valve
S = Solenoid valve
P = Pressure release valve
T = Temperature indicator
T_1 = Cold inlet temperature indicator is common to all six systems
T_5
T_6
V_1
V_2
V_3
To provide drainage at the lowest point in all the six system
acrylic/glass tube (150 mm long and min. 2 mm thick) with manual bypass

Figure 1 Thermosyphon system without heat exchanger and with electrical backup

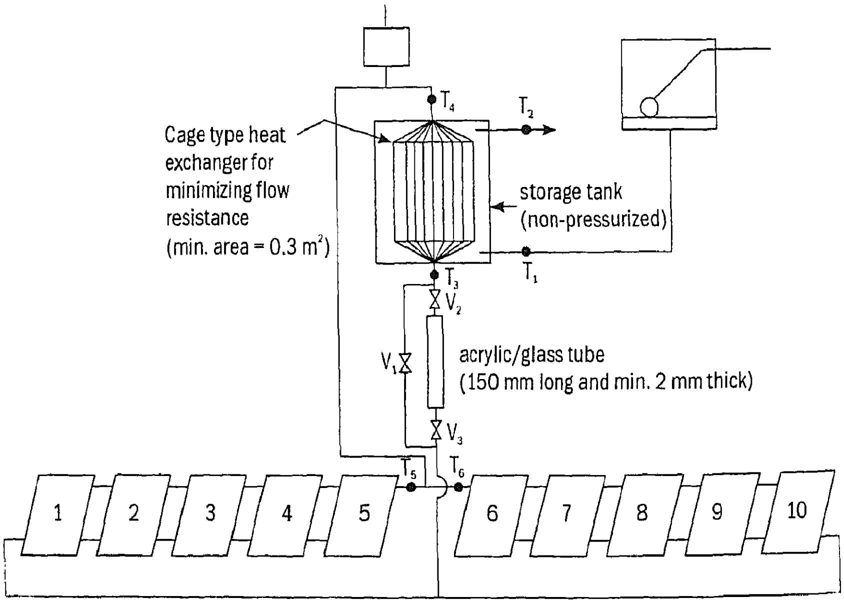

Cage type heat exchanger for minimizing flow resistance (min. area = 0.3 m²)
T_4
T_2
storage tank (non-pressurized)
T_1
T_3
V_2
V_1
acrylic/glass tube (150 mm long and min. 2 mm thick)
V_3
T_5
T_6
1
2
3
4
5
6
7
8
9
10

Figure 2 Thermosyphon system with heat exchanger and no electrical backup

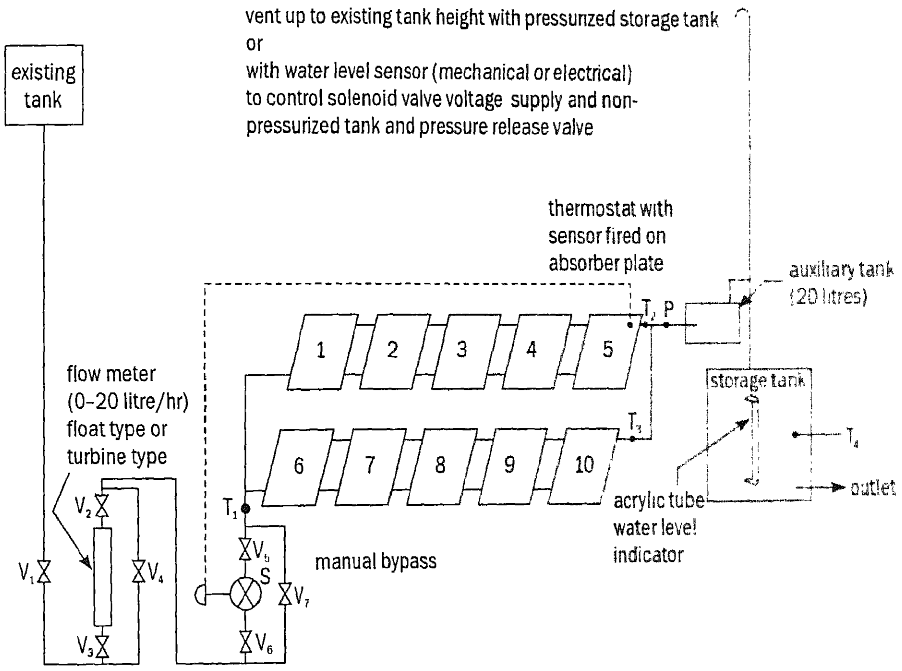

vent up to existing tank height with pressurized storage tank
or
with water level sensor (mechanical or electrical)
to control solenoid valve voltage supply and non-pressurized tank and pressure release valve
existing tank
thermostat with sensor fired on absorber plate
auxiliary tank (20 litres)
T_2
P
1
2
3
4
5
6
7
8
9
10
flow meter (0-20 litre/hr) float type or turbine type
storage tank
T_3
T_4
outlet
acrylic tube water level indicator
T_1
V_1
V_2
V_3
V_4
V_5
V_6
V_7
S
manual bypass

Figure 3 Gravity flow system with a solenoid valve flow controller

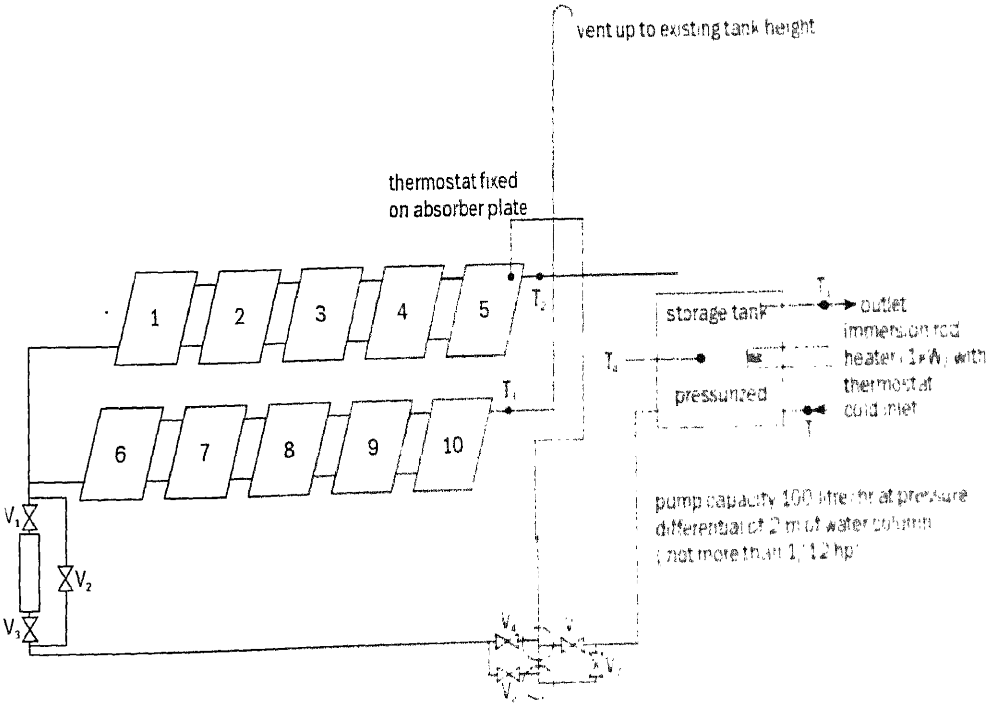

vent up to existing tank height
thermostat fixed on absorber plate
1
2
3
4
5
6
7
8
9
10
T_2
T_1
T_3
storage tank
outlet
immersion rod heater (1 kW) with thermostat
T_4
pressurized
cold inlet
pump capacity 100 litre/hr at pressure differential of 2 m of water column (not more than 1/12 hp)
V_1
V_2
V_3
V_4

Figure 4 Forced flow system (parallel combination) without heat exchanger

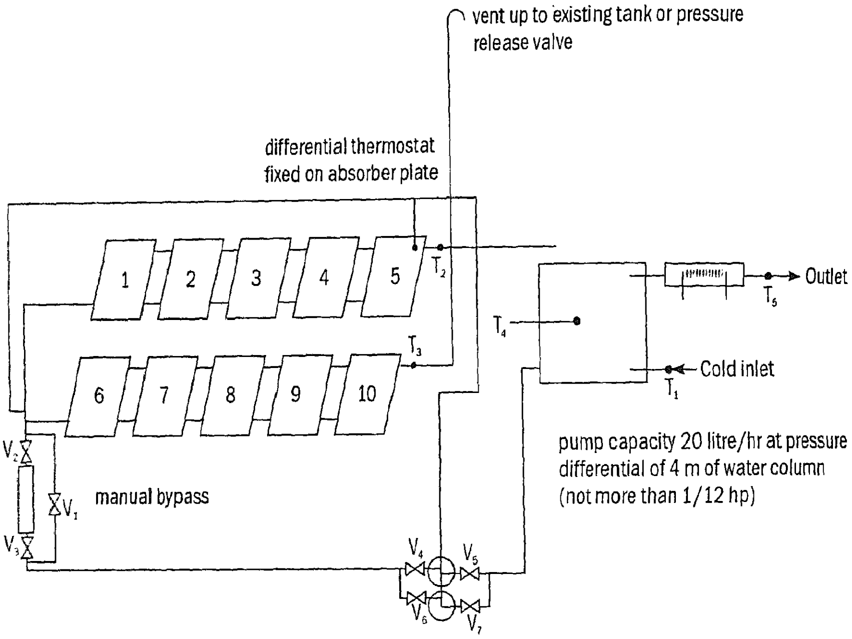

vent up to existing tank or pressure release valve
differential thermostat fixed on absorber plate
1
2
3
4
5
6
7
8
9
10
T_2
T_3
T_4
T_5
T_1
Outlet
Cold inlet
V_1
V_2
V_3
V_4
V_5
V_6
V_7
manual bypass
pump capacity 20 litre/hr at pressure differential of 4 m of water column (not more than 1/12 hp)

Figure 5 Forced flow system (series-parallel combination) without heat exchanger

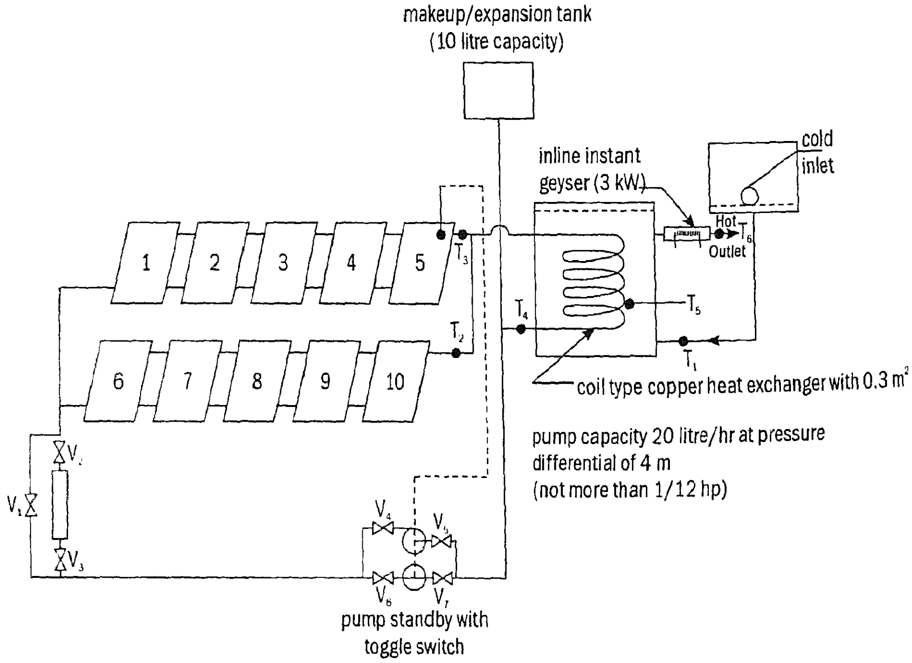

makeup/expansion tank (10 litre capacity)
inline instant geyser (3 kW)
cold inlet
Hot
Outlet
T_6
T_5
T_4
T_3
T_2
T_1
1
2
3
4
5
6
7
8
9
10
coil type copper heat exchanger with 0.3 m^2
pump capacity 20 litre/hr at pressure differential of 4 m (not more than 1/12 hp)
V_1
V_2
V_3
V_4
V_5
V_6
V_7
pump standby with toggle switch

Figure 6 Forced flow system (series-parallel combination) with heat exchanger

Dalen Vidaregaande Skole, 3880 Dalen, Norway

Karl Torstein Hetland*, Einar Oterholm

SOLIS: Solar energy in schools

Renewable energy education: current scenario and future projections
pp. 333-340

Abstract

The SOLIS (Solar energy in schools) project is one of many environmental projects initiated by KUF (the Ministry of Education, Research, and Church Affairs), Norway. This project shows a way of introducing solar energy as a subject in the physics curriculum in the higher secondary schools. The authors' main goal has been to measure the global solar radiation continuously and to use the results as a starting point for a discussion about the potential of solar energy. In this paper, the measuring equipment, some results, and some student projects are presented.

The project started in 1991. In the school year of 1996/97, 55 schools participated. In 1998 there are about 35 active schools. During the year 1997, Finland introduced SOLIS in 10 Finnish schools as part of their new school physics project named $^{S}C_{H}$OOL PHYSICS. Latvia adopted the project in the fall of 1997. In Denmark, SOLIS initiated a daughter project called FotoSOL.

In 1996/97, SOLIS also initiated a national solar energy competition for schools called 'Our Wonderful Sun', and in 1998 Trøndersol '98.

As a result of the SOLIS project, a new project on UV (ultraviolet) measurements has evolved. In this project, the intensity of the solar radiation at 310 nm and 330 nm is measured. From these measurements, the students can calculate the total atmospheric ozone. As far as the authors know, this is the first time such measurements have been carried out in high schools.

---

* Author for correspondence

Background

Over the last few years, a great deal of effort had gone into transferring the conclusions of the Brundtland report into practical EE (environmental education) in Norway. One way of doing this has been through national projects. The main idea behind the projects is that the students make measurements of environmental parameters that are of interest to scientists and the society in general. The SOLIS project is one of these projects.

In March 1990, Astrid Sandås (the leader of EE in Norway) and Einar Oterholm took the initiative of arranging a meeting in Oslo. The question was whether an environmental project on energy issues, especially in solar energy, could be started. The result of the meeting was that a preliminary project group with representatives from upper secondary schools, the Department of Physics (University of Oslo), the Meteorological Institute; and the Department of Education was set up. During the fall of 1990, the group worked out an outline for the project. It suggested that one way of working with solar energy in schools was to use measurement of global radiation as a starting point. The project was to be integrated in the ordinary physics course in the upper secondary school (18 years of age). An accurate gathering of radiation data was to make a sound basis for the project.

To ensure a high professional quality in the project, resource persons from the universities in Norway have been involved in the steering committee and the working group. Each group has representatives from the scientific communities in Trondheim and the Department of Physics, Oslo. The project is financed by the Ministry of Education, Government of Norway and the National Solar Energy Programme. The funding from the National Solar Energy Programme gives the project a high status and is an additional inspiration, both for the students and the teachers.

The final organization was decided in the spring of 1991, and six schools were carefully picked out and invited to participate in developing the project in the first year. At that point, the measuring equipment to be used was not decided and there was no educational working material. The idea was to develop the material in cooperation with the participating schools. The authors held their first workshop at the Solar Observatorium in Harestua near Oslo, in October 1991. At this meeting, the project idea was presented and great enthusiasm for the project was generated. During the autumn of 1991, some measuring equipment useful for the schools was put together. The criteria was that it had to be cheap, easy to use, and could be used to measure other parameters besides solar radiation and temperature. This equipment was tested during spring 1992 and in June all the upper secondary schools in Norway joined the project. The interest shown was far beyond the expectations of the authors when 43 schools applied to join the project. A limit of 20 schools had to be placed and these schools (two teachers from each) were invited to a training course in Dalen, Telemark. On 5 November, radiation data from all over the country were received and there were only minor problems in implementing the equipment.

Measurements

Measuring equipment

In the SOLIS project, the global radiation and the air temperature were measured. A pyranometer, a temperature probe, a data logger, and a computer were used.

The pyranometer is a photovoltaic instrument delivered by SOLDATA A/S in Denmark. The instrument gives an output signal of approximately 150 mV at a global radiation of 1000 w/m^2. To calibrate and control this instrument a KIPP & ZONEN instrument from the Meteorological Institute in Oslo was used (placed at six schools).

The instruments were directed towards the south at an inclination of 45°. The reason for using such an angle was that the results were used to calculate the dimension of solar energy systems for hot water heating in Norway. As a temperature probe, a PT-100 sensor, which measures temperatures between –50 °C and + 50 °C was used.

The signal from these instruments are put into the data logger (Black Star 2308 I/O Interface) through a 12 bits ADC. This data logger has eight analog input channels with an internal memory of 512 bytes each.

Measuring routines

The data logger is programmed to read the instruments every three minutes. The computer program reads the logger at 24.00 hours every night (480 measuring points) and makes a file for each day. The computer presents the data graphically so that the students are able to follow the measurements from minute to minute during the day (the computer is often placed where lots of students pass by during a school day). At the end of every month, the daily data is integrated and we get a result in $kWh/m^2/day$. The mean value for the month is calculated and sent to Dalen.

Measuring results

Monthly results

On the basis of the monthly data from each school, a histogram for the country is made (Figure 1). The places with the highest altitude are placed at the top. In May 1997 there has

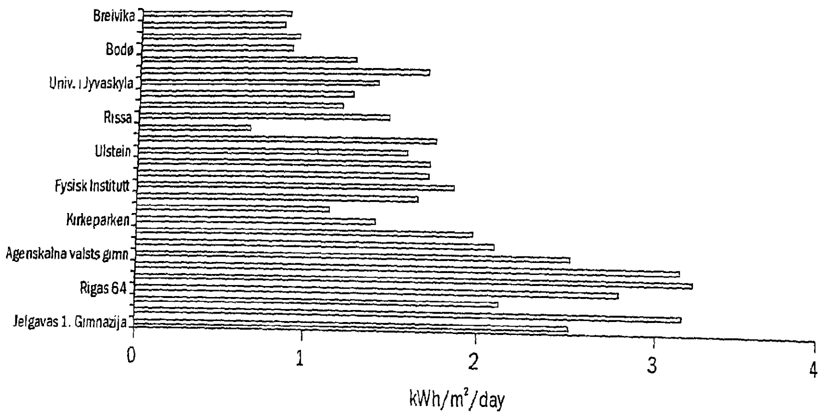


Figure 1 Global radiation (October 1998 kWh/m^2/day)

been as much sunshine in the north as in the south of Norway.

Yearly results

An overview of the total incoming solar energy throughout the country can be got while collecting the data. Figure 2 shows the results from a school in the south of Norway and from a school above the polar circle. It also shows that apart from winter, the north and the south get almost the same amount of solar energy. In general, one can exploit solar energy in the north because available solar energy corresponds well with the heating demands during the summer months (the high altitude paradox).

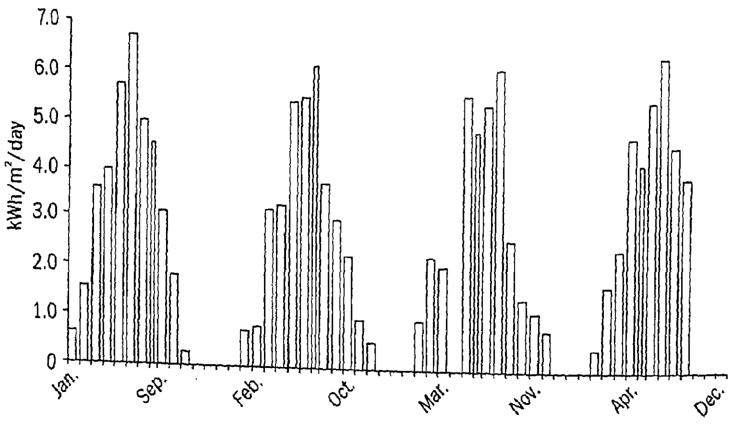


Figure 2a Global radiation (1993-96) from a southern school (Møglestu)

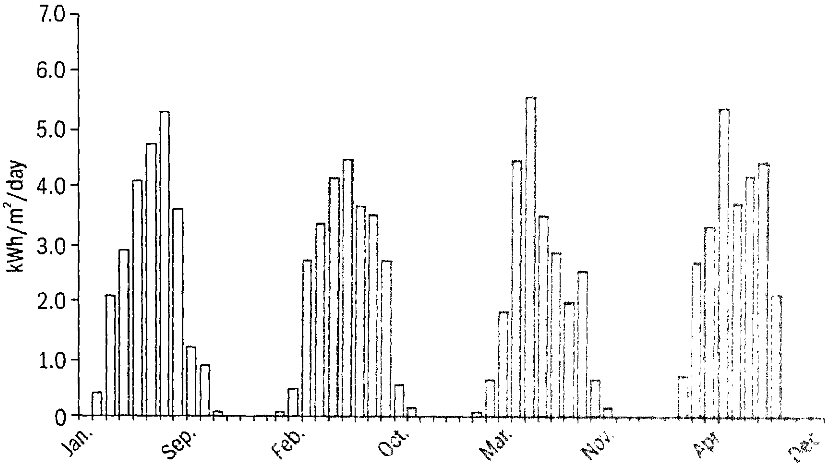


Figure 2b Global radiation (1993-96) from a northern school (Breivika in Tromsø)

Student activities

Organization

This project is integrated into the physics curriculum in the second year in the upper secondary school (2 FY). The duration of the course covers five hours a week and the curriculum includes a project or a special topic expected to have a workload of 20 hours. This project/topic is freely chosen by the schools. The different schools organize the project in different ways. Some let all the students have SOLIS as their project and others let only a part of the class work with SOLIS (chosen by interest). Regardless of this, it is the students who monitor the equipment and make the monthly report. As part of the SOLIS project, a solar energy resource book, is developed (*Solboka*), which the students have as a part of their physics curriculum. In the resource book they may find general chapters on solar energy, project ideas, explanation of the equipment, and references to literature.

Projects

A main idea in SOLIS is that the students will do a solar energy project in addition to the measurements. This can be a theoretical project or a practical project like building a small-scale solar collector or developing photovoltaic applications. Figures 3 and 4 show some of the projects done during the school year 1996/97.

Most of the projects were carried out during the month of May. The schools are encouraged to keep a high public profile. Some of the schools have published informative articles on solar energy in their local newspaper. This will increase the understanding of the general public about how solar energy may be exploited in the future. The experience with the press so far is that solar energy sells!

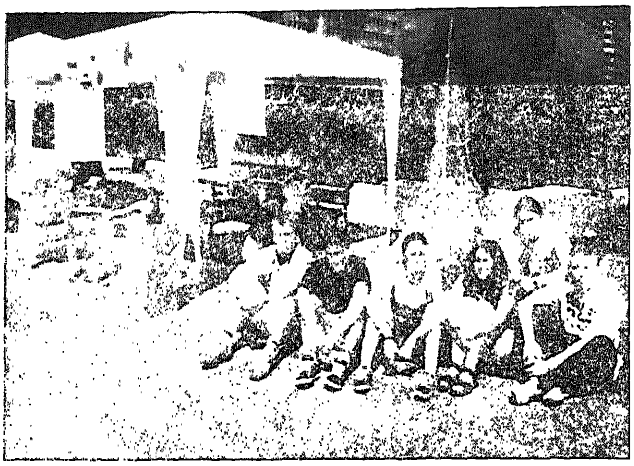


Figure 3 Solar tower (Levanger)

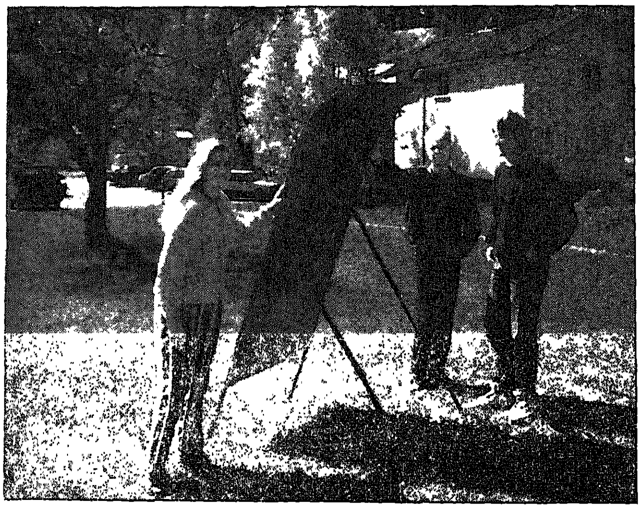


Figure 4 Solar shower (Dalen)

Abstracts of student projects

All the students are encouraged to send an abstract of their project to the coordinator. The abstracts are then distributed to the participating schools. At the moment over 50 abstracts have been submitted. These abstracts can be used by future students for getting ideas for new projects.

International collaboration in SOLIS

The SOLIS project was first presented at the World Solar Energy Conference in Budapest in 1993. Even since, there has been a great interest in the project. From the start, the authors cooperated with Frank Bason from Denmark. In 1993, he introduced a similar project in his country focusing on photovoltaics (FotoSol). During spring 1997, the SOLIS project was started in 10 Finnish schools as a part of the

Finnish Physical Society's focus on physics education. They started a programme called $^{S}C_{H}$OOL PHYSICS.

In September 1997, a Norway–Latvia project was started. Nine schools from each country met to discuss future cooperation. The starting point is SOLIS, but the authors would like to see the project develop into a broad school-to-school collaboration. There has already been a lot of student exchange and the project will at least go on for two more years. For all schools the measurements in SOLIS will be the common marketplace. The World Wide Web will be used as an effective communication tool so that the students can exchange experiences and ideas for new projects.

UV/ozone programme

At the Institute of Physics, University of Oslo, there is a research group in biophysics that works with the effects of UV radiation related to skin cancer. In this research they need to measure the UV doses to which the Norwegian people are exposed to throughout the year. One crucial parameter is the thickness of the ozone layer, but even more crucial is the number of clouds during a day. The clouds absorb almost all the UV radiation. The models prepared by the research group have measurements of the ozone layer in Oslo and Tromsø (north of the polar circle), but the cloud measurements are not very good.

They decided to use the experiences from the solar energy programmes. Along with solar radiation, students also measured how much solar radiation is absorbed by the clouds. The scientists believe that they will get a good estimate of the number of clouds to be put into their models.

As a result of the collaboration with Frank Bason, a fairly inexpensive instrument that measures the thickness of the ozone layer was developed. The instrument measures the radiation at 310 nm and 330 nm. From these two measurements, the thickness of the total atmospheric ozone can be calculated.

In the fall of 1998, 21 schools in Norway will measure the thickness of the ozone layer. At the moment, a lot of care is taken about the quality of the filters and calibration of the instruments. The authors hope that this school year will show that the measurements are of scientific quality. Nevertheless, the project will give the students a hands-on experience with a scientific project.

Discussion of lessons learnt in Norway

SOLIS has great value for different levels in the educational system. The students could apply the basic knowledge of physics which was very exciting. Through an education in solar energy the students learn about radiation physics, thermodynamics, atomic physics, material science, etc., all of which is covered in the ordinary curriculum in a more theoretical way. By using modern measuring techniques, one can measure in a far more realistic way than in ordinary short lab sessions. In addition, it is inspiring, both for the teachers and the students, to know that the results are of interest outside the school community.

The contact between teachers from all over the country is highly motivating. The teachers meet once a year to exchange experiences and by that they get new inspiration which is transferred to their daily work. Cooperation with solar energy scientists is also encouraged, which gives the project a sound scientific basis. The authors feel that the scientists have respect for what the schools can do with respect to scientific work. In almost all the environmental projects in Norway, research institutions have been involved to help set up projects that can give results of interest to the society.

The SOLIS project is part of a national strategy for EE. This strategy document is available in both French and English from the Ministry of Education, Government of Norway.

Ressuressentereti
Miljolaere
6630 Tingvoll
Norway

Einar Oterholm*, Karl Torstein Hetland

Solar energy competition

Renewable energy education: current scenario and future projections
pp. 341-344

Abstract

Pupils and students from nursery schools to universities, in the central part of Norway, were invited last academic year (1997/98) to take part in a competition on the use of NRE (new renewable energy), named Troendersol '98. The objectives of Troendersol '98 were to elevate the level of knowledge among participants about NRE and show the enormous potential in its exploitation, even on latitudes as high as that of Norway.

The exercise provided tremendous opportunity to meet a number of people. Eventually, new projects carried out in schools were given priority in the local media.

The authors recorded a number of activities in the schools such as experiments, model-making, drawing, singing, writing, theatre, exhibitions, and demonstrations.

The SunDay arrangements in Norway consist of an exhibition of scholar projects combined with a promotion of the organizations and companies working with NRE. The most important part of SunDay '98 was the closing of Troendersol '98.

---

* Author for correspondence

Background

Fruitful experiences from one of the national teaching programmes, SOLIS (Solar energy in school), (Hetland and Oterholm 1997a) as well as from a competition project, titled 'Our Wonderful Sun and SunDay '97' (Oterholm and Hetland 1997b) were the basis for Troendersol '98.

In the SOLIS programme, students of physics, drawn from the secondary education level from about 50 schools, measured solar radiation. The results were treated in a central secretariat and returned to the schools to be used as teaching material in class. These activities also generated numerous angles of incident implicit in the exploitation of solar energy. (Please see another paper *SOLIS: Solar energy in schools* by Karl Torstein Hetland and Einar Oterholm in this book. – Editor)

'Our Wonderful Sun' was an attempt to mobilize a lot of children and youth to take part in different activities that could demonstrate the human relationship to the sun and utilization of solar energy. The competition was open to all children and the youth in Norway, from kindergarten to the university level.

The closing of the contest took place as an important part of SunDay '98 – a national event of the ISES (International Solar Energy Society)-Europe's SunDay. At the Euro-Sun '98 conference in Slovenia, the authors received the ISES-Europe Award for the best SunDay arrangement in 1997.

Troendersol '98 and SunDay '98

Troendersol '98 and SunDay '98 were a further development of 'Our Wonderful Sun' and SunDay '97. The scope of this project was enlarged to include all types of RE (renewable energy) sources. In order to gain experience from cooperation with local energy authorities, it was decided to invite only schools in the central part of Norway.

The objectives of the project were to

- give young people positive and concrete experiences in the concept of renewable energy,
- create curiosity and in the concept, and
- impart knowledge about the utilization of renewable energy.

In short, the authors wanted to elevate the level of knowledge about renewable energy and show the enormous potential in its exploitation, even in latitudes as high as Norway's. To fulfil the objectives, the school system was chosen. Students were given the opportunity not only to meet people during their education, but also those who were in contact with pupils and students, their parents, and relatives.

Eventually, 'new' projects carried out in schools were often given priority in the local media.

Organization

The Norwegian Association of Solar Energy and SOLIS programme selected the leader of the project, and invited the energy and school authorities together with universities in the region, to take part as co-organizers. An organization committee with representatives from the invited partners was set up to organize the work and collect financial support.

Teaching material

'Learning by doing' implies the necessity of doing something concrete and down to earth as soon as possible since searching for a suitable literature can take a lot of time.

Solboka (*The Sun Book*), a booklet of 50 pages for pupils 15 years old or more, and a thinner one, *Sola, så klart* (*The Sun, of course*), for the younger ones were distributed. Both the booklets were made for the project 'Our Wonderful Sun'. The Sun Book is a collection of easily accessible theoretical material and concrete teaching ideas. *The Sun, of course* is less comprehensive and contains many drawings in colours.

Courses for teachers

The invitation to join the project was sent out in November, and about 70 teachers from 45 schools accepted the offer of a course. The course included lectures about utilization of solar energy, wind, and bioenergy. A central part of the course was a practical exercise in the construction and building of a solar oven. So many solar ovens were made that every school could take its own device from the course. The evaluation of the course was clear and positive: the teachers went home inspired to start their own projects together with their pupils.

Activities in schools

During January to June, many schools reported a number of hectic and inspiring activities (listed below).

- A lot of experiments and measurements were carried out.
- Many different kinds of sun collectors and equipment to exploit RE were built.
- A number of wall charts and drawings connected to the concept of RE were made.
- Some pupils have found poetry, songs, and drama to be suitable means of expression to convey their message of the sun and its energy potential.
- Influenced by the work of the pupil, several teachers, parents and other interested groups have themselves been captivated by the issues covered in the competition.

Background

Fruitful experiences from one of the national teaching programmes, SOLIS (Solar energy in school), (Hetland and Oterholm 1997a) as well as from a competition project, titled 'Our Wonderful Sun and SunDay '97' (Oterholm and Hetland 1997b) were the basis for Troendersol '98.

In the SOLIS programme, students of physics, drawn from the secondary education level from about 50 schools, measured solar radiation. The results were treated in a central secretariat and returned to the schools to be used as teaching material in class. These activities also generated numerous angles of incident implicit in the exploitation of solar energy. (Please see another paper *SOLIS: Solar energy in schools* by Karl Torstein Hetland and Einar Oterholm in this book. - Editor)

'Our Wonderful Sun' was an attempt to mobilize a lot of children and youth to take part in different activities that could demonstrate the human relationship to the sun and utilization of solar energy. The competition was open to all children and the youth in Norway, from kindergarten to the university level.

The closing of the contest took place as an important part of SunDay '98 – a national event of the ISES (International Solar Energy Society)-Europe's SunDay. At the Euro-Sun '98 conference in Slovenia, the authors received the ISES-Europe Award for the best SunDay arrangement in 1997.

Troendersol '98 and SunDay '98

Troendersol '98 and SunDay '98 were a further development of 'Our Wonderful Sun' and SunDay '97. The scope of this project was enlarged to include all types of RE (renewable energy) sources. In order to gain experience from cooperation with local energy authorities, it was decided to invite only schools in the central part of Norway.

The objectives of the project were to

- give young people positive and concrete experiences in the concept of renewable energy,
- create curiosity and in the concept, and
- impart knowledge about the utilization of renewable energy.

In short, the authors wanted to elevate the level of knowledge about renewable energy and show the enormous potential in its exploitation, even in latitudes as high as Norway's. To fulfil the objectives, the school system was chosen. Students were given the opportunity not only to meet people during their education, but also those who were in contact with pupils and students, their parents, and relatives.

Eventually, 'new' projects carried out in schools were often given priority in the local media.

Organization

The Norwegian Association of Solar Energy and SOLIS programme selected the leader of the project, and invited the energy and school authorities together with universities in the region, to take part as co-organizers. An organization committee with representatives from the invited partners was set up to organize the work and collect financial support.

Teaching material

'Learning by doing' implies the necessity of doing something concrete and down to earth as soon as possible since searching for a suitable literature can take a lot of time.

Solboka (*The Sun Book*), a booklet of 50 pages for pupils 15 years old or more, and a thinner one, *Sola, så klart* (*The Sun, of course*), for the younger ones were distributed. Both the booklets were made for the project 'Our Wonderful Sun'. The Sun Book is a collection of easily accessible theoretical material and concrete teaching ideas. *The Sun, of course* is less comprehensive and contains many drawings in colours.

Courses for teachers

The invitation to join the project was sent out in November, and about 70 teachers from 45 schools accepted the offer of a course. The course included lectures about utilization of solar energy, wind, and bioenergy. A central part of the course was a practical exercise in the construction and building of a solar oven. So many solar ovens were made that every school could take its own device from the course. The evaluation of the course was clear and positive: the teachers went home inspired to start their own projects together with their pupils.

Activities in schools

During January to June, many schools reported a number of hectic and inspiring activities (listed below).

- A lot of experiments and measurements were carried out.
- Many different kinds of sun collectors and equipment to exploit RE were built.
- A number of wall charts and drawings connected to the concept of RE were made.
- Some pupils have found poetry, songs, and drama to be suitable means of expression to convey their message of the sun and its energy potential.
- Influenced by the work of the pupil, several teachers, parents and other interested groups have themselves been captivated by the issues covered in the competition.

- Several schools have arranged exhibitions, which have been visited by parents, teachers, and students alike.
- Some pupils wrote articles for the local press, etc.
- At some schools these activities even resulted in radio and TV coverage.

About 750 pupils, drawn from 28 schools, participated in the project in different ways. Each student was awarded a diploma.

SunDay '98

About 130 pupils from four schools attended the closing ceremony of SunDay '98 held in Trondheim. All the 73 pupils from the Halsa/Blekken School, presented wall charts with solar poetry and symbols, solar shower, sundial, and different solar cookers. The Gauldal Secondary School presented a new, portable and collapsible plan-parabolic solar collector, together with a specially constructed water boiler. The Venn School and the Nesheim School presented wall charts, different models of solar collectors, windmills, and sailing boats. A few organizations and companies presented different products. A solar cap, with a solar-powered fan on the top, was distributed to all pupils and teachers who were present.

Conclusion

This programme has created awareness about RE among pupils in schools as well as the whole community.

References

Hetland K and Oterholm E. 1997a
Solar energy in school
In *Proceedings of the Solar World Congress (1997) of the International Solar Energy Society.* Volume 7. (Online) Available at: www.ises.org

Oterholm E and Hetland K. 1997b.
Solar energy competition: 'Our Wonderful Sun'
In *Proceedings of the Solar World Congress (1997) of the International Solar Energy Society.* Volume 7. (Online) Available at: www.ises.org

80/2 Civil Lines,
Roorkee -
247 667
Uttar Pradesh
India

S P Jain

Evaporative cooling of buildings in hot regions

Renewable energy education: current scenario and future projections
pp. 345-350

Abstract

A new design for optimum utilization of the principle of water evaporation from roof surfaces of buildings has been developed to neutralize the adverse effects of incident solar radiation on buildings down to four storeys. It has been observed, as a result of implementation on a large number of industrial and non-industrial buildings of various types under hot–dry and hot–humid climates of India, that temperatures of the indoor air and that of the structure as a whole (inside surfaces – walls, floor, and ceiling) could be brought down significantly – nearly 2 °C above the outdoor wet-bulb temperatures – the optimum/minimum possible extent, where the natural fundamental principles of heat transfer can help.

The basic aim of developing the new design/technology is to replace air-conditioners and desert coolers, which have been extensively used so far for creating thermal comfort in buildings. Water, which is available at all places, wherever man exists, is the only working fluid in the newly developed indirect evaporation cooling design. Cooling capacity of water could be observed to be very high (about 4 500 litres equivalent to 900 tonnes of refrigeration effect). In this design, solar energy, which normally heats up buildings, has been utilized to evaporate water from roof surfaces to cool buildings. Wind energy, whenever available, enhances the rate of evaporation of water from roof surfaces to help cool buildings.

The basic aims of developing the new improved design have been: (1) to reduce appreciable dead and heat loads on buildings by optimizing thickness of roofs while satisfactorily covering all the functional requirements of roofs, i.e., structure, heat resistance, waterproofing, foot traffic, and impact loading, etc. under large variations of outdoor climatic elements in tropics, and (2) to enhance thermal comfort indoors.

Cooling by natural resources

The simple technology consists of laying a thin, uniform, organic, fibrous lining of specific nature on roof terraces in their close contact after ensuring a uniform smooth run-off gradient on roofs. The material lining is constantly maintained in water-soaked condition day and night throughout the hot periods for constant and quick evaporation of water from roof surfaces.

The RSE (roof surface evaporation) cooling technology has been observed to achieve the following main objectives.

- It brings indoor dry-bulb and inside surfaces temperatures close to the outdoor wet-bulb temperatures both under hot–dry and hot–humid climates, so as to provide dry, natural, and pleasant cooling effect, in all the floors down to 4 storeys consuming only about 2 per cent of the energy taken by air-conditioning and not causing any pollution of outdoor environment.
- It boosts low-cost housing schemes including multi-storeyed ones and even the poorest can enjoy adequate thermal comfort in their low-cost hutments.
- It works as a boon for workers in industrial buildings who suffer from worse thermal discomfort conditions as compared to residential buildings.

This simple technology has been successfully implemented in more than 625 buildings at different hot places of India. Thousands of people utilized this technology themselves on watching television programmes and attending nearly 70 popular lectures in different parts of the country. In the recent past, successful implementation has been made in the following important buildings.

- Solar Energy Centre buildings under Ministry of Non-conventional Energy Sources, Government of India, New Delhi. There are 60 cylindrical shell roofs, each 50 m^2 in area and 8 cm in thickness.
- Navodaya Vidyalaya multipurpose hall (an area of 30x20x9 m) with AC (asbestos cement) sheet roofs at Gauriganj, Uttar Pradesh.
- Y-shaped multi-storeyed building of CPWD (Central Public Works Department), Indraprastha Bhawan, New Delhi.
- Abhilasha Eye and Maternity Nursing Home at Railway Road, Roorkee having RCC sloped roof.
- CPWD training centre, having GI (galvanized iron) sheet sloped roof (115 × 21 feet) in Netaji Nagar, New Delhi.
- Residence of Mr B K Jain, Senior Engineer, Uttar Pradesh Irrigation Research Institute, Roorkee.

- Residential buildings in Nazir Manzil, Sir Syed Nagar, Aligarh.
- Utilization of natural effective cooling on AC sheet roofs by Major V K Pande, 902 ADMSI Building, Roorkee.
- Prof. N C Varshney and Prof. Bani Singh of University of Roorkee, on their residential building in University of Roorkee campus, Roorkee.
- Residential buildings of Dr Pradeep Rastogi, dental surgeon in Roorkee.
- Office buildings of Continental Device of India Limited, New Delhi.
- Lift machine room of 15-storeyed buildings of Shakti Bhawan, Lucknow.
- Administrative block of Non-conventional Energy Development Agency at Chinhat, near Lucknow.

Brief accounts of the actual application details of RSE on three important sample buildings, which have been working satisfactorily for the last three to five years are given in the following pages.

The working design could be provided by the author only.

Air-conditioned buildings of Continental Devices of India Limited

A roof area of nearly 2400 m^2 of the above building was treated with RSE system utilizing coir matting, automatic electronic water spraying controller, pump, carbon sensors and solenoid valves. The roof was first treated with China mosaic, duly embedded with cement–sand plaster mixed with inorganic waterproofing solution, to prevent any leakage of water inside the building, i.e. not to disturb the indoor activity of manufacturing sensitive electronic components under highly controlled conditions of temperature and humidity.

According to their recent reports, the system has been running satisfactorily for the last five years. As per their standard maintenance procedure, they have been checking the various gadgets of this cooling system very often.

As per their controlled experiment, the following advantages were observed and reported by them after utilizing this cooling system.

Besides achieving a large saving in energy consumption for air-conditioning the portion in which work is carried out round the clock for 365 days, there was a lowering of 1 °C in an open area with high number of door openings, and lowering of at least five tonnes purely in AC terms could be achieved.

Thermal data in terms of temperatures for an unconditioned portion treated with RSE system is presented in Table 1.

Table 1 Indoor temperatures after the installation of RSE in the buildings of Continental Devices India Limited

	Hour of the day									Ambient
Date	0930	0930	1030	1130	1230	1330	1430	1530	1630	maxima
16 June	28.0	27.0	27.4	27.0	27.5	27.5	28.0	28.2	28.5	42.3
17 June	27.0	28.0	28.5	28.5	28.0	28.0	28.5	28.5	29.0	42.2

Recently, the CDIL Deputy Manager (Projects) has also reported that they treated reception portion of their building with a 1.5 tonne split AC but the receptionist reported discomfort without the running of RSE system on his roof portion. The manager has also reported that they could recently extend the heat insulation/cooling and waterproofing system on their other roofs (500 m^2 in area) by themselves using glossy white China ceramic tile treatment to reduce heat loads on their big air-conditioned building.

Solar Energy Centre buildings at Gual Pahari

On discussions with the Principal Scientific Officer and Adviser of SEC (the Solar Energy Centre) of MNES (the Ministry of Non-conventional Energy Sources), Government of India, the RSE system was recommissioned by the author on 30 shell roofs of 50 m^2 each, with modifications in the automatic water spraying system, i.e. substituting newly-developed digital electronic timers to automatically spray water for two minutes after every 30 minutes. The old materials like brass nozzles, coir matting, pumps, GI pipe grid (except solenoid valves, electronic controllers, and sensors) were utilized after necessary cleaning and required resetting and adjustments on turnkey basis. The adviser of SEC suggested running the system without any staff assistance. The RSE system was duly upgraded as desired and reinstalled technically to meet the requirements of the advisor.

The cooling system worked efficiently and effectively with effect from April 1996 to September 1996. Each month, the author visited the centre to inspect and ensure the smooth functioning and monitor the performance of the system. It worked smoothly and independently without any staff assistance, as desired by the adviser. Also, a civil engineer of the centre was trained to maintain the cooling system. Temperatures were scanned with the help of a psychrometer for recording dry and wet bulb temperatures outside and inside various treated buildings. Invariably, the indoor temperature was observed to be nearly 1 °C above or equivalent to the outdoor wet-bulb temperature, as in several buildings treated earlier. The system also worked efficiently due to the specially designed water spray nozzles and the shell roofs for uniform spraying on the entire roofs as per the author's original design during 1987–89.

During July–September 1996, under hot–humid periods, dry, pleasant, and cooling effect was observed besides the above-stated drop in indoor temperatures. The work supervisor sent a satisfactory performance report of the cooling system during both hot–dry and hot–humid periods.

Later during 1997 and 1998, the adviser reported smooth management of the cooling system by the staff, really giving the effect of self-transference of the simple technology.

Lift machine room of Shakti Bhawan, Lucknow

In April 1996, the Chief Engineer (Civil) of UPSEB (Uttar Pradesh State Electricity Board) proposed utilization of RSE system to cool their lift machine room measuring 1200 square feet located at the top of the 15-storeyed Shakti Bhawan building in Lucknow. The room houses heavy equipment and sensitive relays which produce a lot of heat due to their chattering and sparking in operating high-speed gearless lifts. Excessive heat generation made it difficult to maintain desired temperatures, even after utilizing (1) 10.5 tonne window-type ACs and equal tonnes of cooling through diffusers fitted in the false ceiling (2) seven pedestal fans, and (3) 5.2 cm-thick layer of styropore (commercially known as Thermocole) and concrete above the RCC roof with tarfelt laid over.

As a consequence of excess heat loads, the lifts malfunctioned and people had to utilize the stairs. In view of the costly equipment housed inside the machine room, the roof was first treated with ceramic glazed tiles for perfect waterproofing. These tiles were placed after removing the tarfelt and Thermocole, and thrashing the lime–concrete layer to half its thickness. The false ceiling with its aluminium frame and AC sheets were also removed so that the hot air draught would reach the ceiling surface and be extracted through the treated cooled roof surface. Finally, coir matting with six sprayers, an electronic digital timer, and a pump were installed as per basic requirements of the RSE system to spray water automatically for two minutes after every 30 minutes. Prior to the treatment, if the outside temperature was 30 °C, indoor temperature used to be 70 °C–80 °C and once fire also broke through. Now with the RSE cooling system, if the outside temperature is 30 °C, the indoor temperature is also nearly the same without any air-conditioning, pedestal fans, styropore on roof top, and false ceiling. The new cooling system has been functioning and performing satisfactorily since 1996.

Conclusion

The solar-passive cooling technology based on their actual application and performance adopted in actual practice, can bring revolutionary changes in the construction of low-cost, comfortable, durable, and maintenance-free buildings in the tropics to improve quality of life for sustainable development. This simple natural technology is therefore, recommended, in principle, for mass-scale utilization in the hot and humid regions of the earth.

Index

Renewable energy education: current scenario and future projections
pp. 351-362

- Acid rain 109, 285
- Action for food production (*See* AFPRO)
- Active solar air heating 64
- Adult literacy programmes 225
- Advanced
  - computer simulations 45
  - photovoltaic engineering 43, 45
  - solar energy engineering 44, 46
  - solar materials 45
  - solar thermal engineering 43, 45
  - undergraduate level training 80
- AEPC, Nepal 140
- Aerodynamic design 71
- Aerodynamics 80, 86
  - wind turbines 84
- Aerospace 84
- AFPRO 122, 123, 125–129
- Agency for Non-conventional Energy and Rural Technology (ANERT), Thiruvanthapuram 194
- *Agenda 21* 43
- Agricultural
  - land 93
  - production 157
  - residues 134, 295
  - University of Norway (AUN) 35, 36
  - waste 295
- Agriculture 145
- Agro-businesses 157
- Air
  - release valves 326
  - separators 318
  - vents 318
- Airfoils 84
- Airscrew theory 84
- Alcohol thermometers 313
- All India Council of Technical Education (AICTE) 152
- Al-Sharqiya governorate 92, 99, 100
- Alternative
  - energy 58
  - energy resources 180
  - fuels 78
- Amazon rain forest 18
- Ambient energy 192
- American university, Basaisa-IRTECTAP 92
- American University in Cairo 92
- Anacapri, Italy 46, 47
- Analytical capability 79
- Anemometers 84
- Animal
  - power 295
  - residues 145
  - waste 134
- Anna University, Chennai 181
- Apogee exhibits 56
- Applied
  - electronics 116
  - mechanics 116
  - rural sociology 117
  - science curriculums 69, 71, 72
- Appropriate technologies 95, 101, 113, 155
- Architects and Engineers Association 194
- *Arthashastra* 81
- Artificial intelligence 201
- Association of Architects 194
- Atomic energy 202
- Audio-visual
  - aids 60
  - material 19
- Automatic data acquisition 40
- Automobile engineering 114
- Auxiliary heat 320, 321

- Ball valves 318
- Basaisa community development association 92, 94, 99
- Basaisa-IRTECTAP 92-94, 98
- Bioclimatological
  - construction 164
  - designs 160
- Bio-conversion 180
- Bio-diesel 294
- Bioenergy 40, 49, 55, 180, 222, 232, 237, 284, 287, 294
- Bio-ethanol 294
- Biofuels 39
- Biogas 59, 71, 90, 97, 100, 121, 223, 247, 301
  - plants 28, 73, 96, 100, 121, 126
  - technology 95
- Biological
  - damage 59
  - totality 59
- Biomass 29, 33, 35, 39, 71, 78, 95, 97, 109, 121, 134, 145, 200, 205, 247, 294, 303
  - conversion technology 21
  - energy 8, 111, 121, 301

  fuels 145
  gasifiers 121
  heat 39
Briquetting 294
Brundtland Report 43
Building
  energy 195
  energy management 192
  materials 203
  sector 197
  softwares 192, 197
Bureau of Indian Standards (BIS) 205
Butane 160

Calle Caballero 157, 158
Capacity building 104, 105, 120, 121, 122, 128
  on rural energy 125
Casa Solare 46, 47
Central Building Research Institute 195
Centre for
  Adult and Continuing Education (CACE) 92
  Electro-Chemical and Electrical Research 56
  Energy Studies (CES) 74, 174, 181, 196
  Environmental Studies (CES) 69
  Renewable Energy and Environment Development 50, 56
  Rural Technology 106
  Scientific Research 154
CEPEL (Brazilian Research Centre in Electrical Engineering) 275
Chanakya 81
Chemical
  conversion 304
  energy 303
  engineering 57, 76
  engineers 78
Chulhas 149
Civic
  commitment 19
  engineering 57, 201, 202, 205
  engineering degree 166,199
Civil engineers 200
Classification of climates, India 197
Classroom
  demonstrations 76
  lectures 168
  training 86
Clean energy technologies 15, 247
Climate change 98
Climate-responsive architecture 190, 191
Climatic classification 191
CNR (Italian Research Council) 46, 47
CNRSE (Centre for New and Renewable Sources of Energy) 110
CO_2 emissions 18, 159, 200, 250, 252, 286
Coal 134, 145, 180, 200
Coastal areas 70, 80
Cogeneration 105, 295
Collection systems 72
Collector 45
  base support 322
  top support 323
Collector-to-collector joints 324
Combustion engine 202
  process 39
  system 39
Commercial fuels 145, 149
Communal production 99
Community
  action programmes 61
  development 95
  education 149
  needs 95
  PV 242
  training programme 147, 148, 150
  -based activities 92
  -oriented energy education 59
Compressible fluid flow 203
Computer applications 116
  industry 167
  modelling 46
  programmes 61
  simulations 45
  software 195
  -aided simulation 196
  -assisted learning (CAL) 185
Computerized data bank 6
Concentrators 71
Consumption patterns 59
Control system 39
Controls and sensors 326
Conventional
  energy 16, 149, 171, 200
  energy gadgets 51
  energy sources 147, 208, 226, 300
  energy systems 56, 297
  engineering 69, 71, 72
  grid 145
  solar still 55
Conversion technology 94
Cookstoves 28, 121
Council of Scientific and Industrial Research (CSIR) 176
Credit system 152
CREED (*See* Centre for Renewable Energy and Environment Development)
CREST (Center for Renewable Energy and Sustainable Technology) 229
CRICYT 154, 157
Crop residues 145
CRT (Centre for Rural Technology) 133, 135, 136, 138, 139
Curriculum development 89, 115, 202
Cylindrical shell heat exchanger 320

Darreius wind turbine 38
Data
  acquisition systems 39, 40
  collection 40, 95
  control 40
  logger 335
  presentation 40

  processing 95
  storage techniques 19
Databases 22
Daylighting 192, 195, 197, 201
  strategy 191
Deforestation 145
Demand pattern 180
Demand-oriented training 89
Desert
  architecture 96
  areas 89, 94, 98
  communities 94, 95
  community development 88, 101
  development 88, 92
  development research centres 96
Developed countries 19
Developed country universities 18
Developing countries 11, 15, 16, 18, 19, 24, 25, 108, 109, 121, 184
Developing-country
  audiences 17
  scholars 18
Development
  communication 98
  of interactive teaching modules 187
  of Internet activities 186
Diesel power plants 275
Digesters 90
Distillation 46
Distillers 100
Domestic energy 145
Domestic hot water production 35
Drier unit 100
Duct tape 66

Earth Summit: United Nations Conference on Environment and Development 14, 15
Earth-coupled building 197
ECN (Netherlands Energy Research Foundation) 294
Eco-community development 101
Eco-desert 98, 101
Ecological
  catastrophes 18
  hazards 25
Ecological-environmental studies 60
Economic
  analyses 89, 117
  consequences 145
  development 145, 146
  growth 25
  problems 19
  sector 16
  viability 17, 146
  perspectives 149
Economy 58, 71, 91
Educated unemployed rural youth 149
Education 70, 94, 147, 206, 208–210, 213–215, 220, 221
  and training 89, 147
  management 72, 73
  process 68
  television 228
Educational
  aids 250
  films 229
  material 63, 68
  material development 62
  media programmes 247
  network 6
  package design 62
EE 27, 58–60, 70, 74, 77, 104, 120, 146, 334, 340
EE modules 59
Eemultimedia 130, 252-254
Effective TLS 68
Efficiency and energy 195, 252
Efficient tools for solar energy education 157
Eighth Five-year Plan 146
Electric
  power generation 28, 86
  vehicles 238
  bicycle 35
Electrical
  energy 200, 202, 290
  engineering 76, 84, 86
  lighting 201
  power 39
  technology 202
Electricity 96–98, 135, 139, 202, 303
  consumption 190
  generation 71
Electrification 221
Electromagnetism 40
Electronic
  communication technologies 228, 231, 235
  mail 57, 182
  media 229, 264
  technologies 227, 229
E-mails (*See* Electronic mail)
Emissonmeters 174
Energetics 303
Energy 59, 70-72, 79, 95, 111, 167, 201, 202, 253
  alternatives 50
  and ecology indicators 251
  and environment 95
  and Environment education 24
  and environmental pollution 180
  and society 21
  areas 175
  auditing 59, 180, 204
  awareness 76
  clubs 61
  conservation 20, 26, 58, 59, 68, 74, 77, 95, 173, 192, 203, 286
  conservation and management 152, 179, 180, 181
  conservation, agriculture 21
  conservation, boilers 180
  conservation, transportation 21
  consumption 58, 59, 134, 190, 200, 202
  consumption analyses 255
  conversions-concentrators 95
  crisis 59, 180
  demand 27, 284, 290
  demand management 25

economics 20
education (*See* EE)
education, capacity building 106
Educators Association Conference 6
engineers 17, 18, 22, 29
forms 95
from waste 21
industries 167, 176
intervention 125, 127
management 180, 181
management principles 180
mix 285, 296
modeling 20
park 56, 149
performance 161
planning 17, 21, 124, 127, 146, 209, 295
planning and policy 21
planning specialists 23
policies 17, 70, 78, 180, 312
problems 150
-related industries 176
requirement audit 199
research 176
research methodologies 148, 152
resources 59, 149, 152, 192
resources, commercial 70, 180
resources, non-commercial 180
resource-technology combinations 26, 27
saving 149
security 285
sources 98, 251, 263
specialists 176, 178
storage 45
studies 78, 166, 169, 170, 173, 177
supply 25, 89, 33, 209, 215, 251
system layout problem 187
systems, decentralized 146
technologies 26, 89-91, 123, 181
use 60, 180, 201, 205
Energy-conscious
architecture 197
industries 147
Energy efficiency 25, 154, 160, 197, 198, 242, 287
analysis 180
programmes 61, 68
Energy-efficient
buildings, 192, 195-197, 203
construction process 202
designs 154
houses 104,154, 157, 158
lighting 195
technologies 68, 193
usage, economics 180
windows 195
Energy-environment scenario 33
Engineering
aspects 89
drawing 116
education 13
educational institutions 80
geology 202
graduates 79, 147
students 35, 77
training 13
Environment 80, 89, 91, 95, 98, 111, 145, 239
pollution 304
protection 19, 50
social and economic benefits 89
Environmental
aspects 79
awareness 17
consciousness 27, 34
conservation 59
costs 91
degradation 27, 59, 134, 135
education 27, 34
engineering 111, 203
engineering systems 204
hazards 25
impact assessment 59
impact assessment study 200
impacts 94
implications 25, 27
issues 60
management 21, 59, 78, 201
perspectives 149
physics 34, 36
pollution 149, 204
protection 20, 74, 94
sanitation 204
scanning 288
studies 78
systems 201
tragedies 18
sound technologies 201
friendly policies 159
Environment-friendly
building 197
industrial development 58
ES specialization 171
ESES (European Solar Engineering School) 34, 43, 46, 47
EU 46
EU white paper on RES 1997 43
Europe 43, 81, 83
European Union (*See* EU)
Euro-Sun '98 342
Evaluation methodology 48, 51
Evaporative cooling systems 197

First International Symposium on Renewable Energy 9
First World countries 155, 159
First World Renewable Energy Congress 5, 8
Fixed temperature systems 319
Fixed-flow system 319
Flat plate collectors 71
Flexible educational programmes 49
Fluid
mechanics 83, 202
transport 36
transport processes 36
Fluidyne principle 40
FONAVI 155, 156, 159, 160
Forced flow systems 316, 318, 320, 322, 331, 332

- Formal education 147
- Fossil fuel
  - imports 25
  - power plants 81
  - resources 284
- Fossil fuels 25, 81, 134, 160, 180, 183, 200, 202, 250, 284
- Free energy concept 304
- Fuel cells 21, 52, 57, 304
- Fuel
  - rates 135
  - shortages 135
  - sources 56
  - value 175
- Fuelwood 90, 134,145, 149
  - consumption 134
  - problem 15
  - supply 145
- Futuristic technologies 70

- GATE 147, 152, 167, 175–177
- Gate valves 318
- GDP (gross domestic product) 134
- Generators 98
- Geostrophic trade winds 80, 84
- Geothermal
  - energy 21, 29, 52, 98, 202, 232, 303
  - technologies 111
- GHGs (greenhouse gases) 81, 83, 285
- Global
  - climate change 287
  - energy 33
  - energy scenario 179, 180
  - energy supplies 109
  - Environment Facility (*See* GEF)
  - environmental protection 83
  - radiation 333, 335–337
  - renewable energy education and training 11
  - society 27
  - solar irradiance 41
  - warming 33, 59, 109
  - wind systems 84
- Globalized economy 185
- Graduation Programme in Energy, Environment and Materials (*See* PPGEAM)
- Gravity flow system 331
- Green electricity 238
- Green energy 238
- Greenhouse effect 286

- Harare 9, 12, 167
  - Declaration 12
- Hard currency countries 8
- Harvested energy 37
- Health hazards 149
- Heat
  - and power production 35
  - engines 39,116
  - exchanger, cage type 320
  - exchangers 319
  - gains 160
  - transfer 110, 202, 308
- Heating
  - energy 200
  - systems 67
- Higher
  - degree programmes 49
  - education 50
  - secondary schools 333
  - studies 76
- High-school graduates 93
- Högskolan Dalarna 43, 46
- Hot
  - air engine 39
  - water 197
  - water supply line 319
  - water tanks 317
  - water tap 37
- Household
  - energy consumption 149
  - sector 145, 146
- Housing and Urban Development Corporation, New Delhi 194
- Housing programmes 158
- Human
  - capital 108
  - development 98
  - resource development 14, 29, 147, 166, 183, 206, 208, 217, 220
  - resources 115
- HVAC (heating, ventilation, and air-conditioning) 201
- Hybrid
  - power plant 150
  - PV system 45, 52, 274, 277
- Hydraulic machines 116, 203
- Hydro energy 8
  - sources 284
- Hydropower 134, 180, 283, 287, 291
- Hydroelectric
  - energy 301, 303
  - power stations 303
  - units 90
- Hydroelectricity 109
- Hydrogen
  - energy 21,180, 304
  - fuel 203

- IASEE (International Association for Solar Energy Education) 5, 7–9
  - Advisory Committee 7
  - Board of Directors 8
  - Membership 8
  - Secretariat 7
  - Discussion List 7
  - IC engine 150
- IEB (Institution of Engineers, Bangladesh) 69, 72, 73
- IIT 26, 71, 174, 195
  - Chennai 181
  - Delhi 34, 74, 181
  - Kanpur 80, 81, 86
  - Kharagpur 175
  - Mumbai 181
- Impact-oriented comprehensive approach 74
- Improved cookstoves 59, 175
- Indian
  - energy scenario 179, 180
- Institute of Technology (*See* IIT)
  - Renewable Energy Development Agency (*See* IREDA)
- Indoor *chulhas* (cookstoves) 168

Industrial energy
  environmental management 78
  conservation 21
Industrial
  management 116
  pollution 59
  process heating applications 28
  R&D work 45
  revolution 81
  Technical Institutes 147
Industrialized countries 11, 184
Industry and academia 86
Inefficient houses 156
Informal education 147
Information
  dissemination 115, 127, 128
  revolution 185
  technology tools 34
  transfer 127, 220
Infrastructural facilities 176
Infrastructure 60
Institution of Engineers 194
Insulation 315, 317
Insulators 67
Integrated
  energy planning and economics 148, 152
  first degree programmes 49
  rural development 144
  rural energy planning and development 106
  Rural Energy Planning Programme (*See* IREP)
  water pumping systems 112
Interactive teaching modules 187
International Conference on Education 14
International financial institutions 154, 155
International Solar Energy Society (*See* ISES)
International Symposium on Renewable Energy Education (*See* ISREE)
International System for Energy Expertise and Knowledge database 22
International Union of Technical Associations 15
Internet 38, 57, 167, 229, 231, 235, 236, 239, 245
  in renewable energy education 166, 182
  options for international cooperation 183
Interpersonal communication 263
Inter-sectoral coordination 16
IREDA 125, 146, 195, 291
IREP 107, 146, 147, 148
ISES 6, 9, 342
  Board Meeting 8
  Solar World Congress 6
  Working Group 6, 8
  Working Group Committee 6
  Working Group on education 8
  World Congresses 9
ISO standards 79
ISREE 7
  series 10
ISREE-1 proceedings 9
ISREE-2 9
ISREE-3 9
ISREE-4 9
ISREE-5 10
ISREE-6 10

JNNSEC (Jawaharlal National Science Exhibition for Children) 305
Journal of solar education 7

Kenouz Sinai 99, 101
Kerosene 145
KIPP & ZONEN instrument 335

LabView 40
Landscape architecture 36
Letter grading 49
Life cycle assessment 201
Lighting 146, 191, 200, 202-205
Liquid level controller 319
LoadAnalyse 272
Local
  communities 148
  governments 154
  manufacturing, renewal energy products 90
  markets 90
  production 91
  solar radiation data 36
  weather 155
Logging system 37
Long-term education 15
Low temperature range 97
Low-cost
  communications 19
  housing schemes 346
Low-income workers 157
LPG (liquefied petroleum gas) 135, 140, 141

M. Sc. programme on Energy Studies 167
M. Tech. (Energy Management) programme 313, 329
Magneto-hydro-dynamic power generation 21
Maharashtra Energy Development Agency 196
Maintenance of RES 149
Manipur Science and Technology Council 196
Mass
  communication 73, 69, 263
  media 264
  media techniques 26
Material
  science 111, 116
  selection 210
Mechanical engineering 57, 86, 114, 116
Medium temperature range 97
MGIIREPD (Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development) 147, 150
Micro hydro energy 98
Microeconomic 89
Micrometeorology 36
Microprocessor-based solar

energy 309
Mid-day solar altitude 160
Mini-hydro energy 21, 98, 111
Ministry of Non-Conventional Energy Sources (*See* MNES)
MNES 55, 146, 173, 190-192, 314
Model desert farm 96
Modern industrial society 180
Monsoon winds 80, 84
MS heat exchanger 320
MS tanks 317
Multimedia 229, 231, 235, 239
Multipass force-flow system 318
Multiple-point entries 49
Municipal governments 155
Municipalities 160, 164

National Council of Educational Research and Training 26
National
  laws 46
  programme on improved *chulhas* 264
  project on biogas development 264
  Social Housing Fund 155
  Solar Energy Programme 334
  training programmes 150
  training-cum-R&D centre, Delhi 147
Natural
  air conditioning 99
  cooling 282
  gas 180
  resources 58, 282
  ventilation 201
NCERT (National Council of Educational Research and Training) 305
NET 167, 176
New and renewable Sources of Energy 173
New Basaisa 88, 98, 99
NGOs 15, 91, 94, 99, 100, 104-106, 115, 120, 122-130, 154, 157, 158, 164
Non-conventional
  energy appliances 150
  energy sources 147, 171
  renewable sources 203
Non-formal education 71, 225
Non-government organizations (*See* NGOs)
Non-renewable energy 75
  sources 94
  technologies 285
  resources 200
Nordic Solar Energy R&D Meeting 9
Norwegian Association of Solar Energy and SOLIS project 343
NRE 341
NREL (National Renewable Energy Laboratory) 238
NSS volunteers 55
Nuclear
  catastrophes 18
  energy 200
  energy sources 284
  fusion 303
  power generation 183

Ocean energy 287, 292
Ocean energy systems 52
Ocean thermal energy 8, 29, 284
Ocean thermal
  energy conversion 21
  power 292
Oil crisis 25, 27
Open air laboratories 88
Open work market 94
Operational research in energy systems 148, 152
Orissa Renewable Energy Development Agency 194
Ossietzky University, Oldenburg, Germany 6
OTEC (Ocean Thermal Energy Conversion) 292
Our Wonderful Sun and SunDay '97 342
Ozone layer 59

Padded insulation 315
Parabolic
  cookers 140, 106, 136
  reflectors 138
Passive building
  concepts 197
  technologies 196
Passive solar
  architecture 190, 191, 196, 199, 202, 204
  designs course 46
  energy 156
  energy designs 163
  energy devices 154
  energy education 160
  energy houses 160
  energy principles 157
  energy techniques 46
  engineering 46
  system designs 160
  systems 255
PD (population density) 93
Pedagogic methods 60
Petroleum 200
Photochemical decomposition, water 304
Photosynthesis 203
Photothermal 174
Photovoltaic (*See* PV) 100, 105, 238
  charging dairy 37
  energy-driven water pumps 74
  orientation 125
  panels 37
  systems 35, 95, 146, 267, 309
  systems design 308, 309
PiSEE 5, 9
Planning
  and governance 90
  and management 89
  regulations 160
Plaster of Paris 65
Pneumatic control 116
Poisonous gases 145
Polar cell 84

Policy
  discussions 89
  framework 52
  framing 59
  issues 86
  makers 13, 58, 81, 119,
  matters 80
Pollutants 59
Pollution control 50
Population 93, 98, 191
  distribution 92
  growth 145, 93
Postgraduate
  courses 89, 167
  degree final semester 50
  diploma programme 147
  diploma, rural energy technology 152
  engineers 81
  level 72, 74, 80
  programmes 73, 313
Potential
  energy solutions 27
  energy supply options 27
  programmes 13
Poverty 115, 145
Power
  conditioning of PV systems 308
  generation 284, 290, 295
  generation, grid connected 27
  management 78
  plant operation performance 71
  sector 145
  shortages 135
  supply system 275
  system 202
  train design 86
PPGEAM 267, 268, 277
Practical
  applications 36
  demonstrations 53
  work 100
Primary
  energy supply, commercial 284
  level 75, 225
Private sector 98
Problem-solving skills 62
Progress in Solar Energy Education (*See PiSEE*)
PT-100 sensor 335
Public
  awareness 88, 92
  courses 89
  education 17
  interest 190
  policy makers 33
Puppet shows 61
PV 36, 76, 200, 236, 248, 267
  accumulators 36
  applications 174
  cell 202, 203
  Charging System 36
  code 269, 274, 277
  devices 180
  generator 187
  generators 272, 275
  industry 45
  modules 78
  panels 46, 309
  power 201, 223
  sizing 272
  systems 46, 72, 126, 180, 255, 228, 237, 269, 274, 277
  technology 128, 129, 242
  -powered information display systems 77
Pyranometers 174
Pyrheliometers 174

Quality control 176
Quality degree programmes 50

R&D 45, 92, 147, 176, 191, 192
  activities 148, 150
  projects 192
  work 45
Radiation data 311, 335
Rajasthan Energy Development Agency (*See* REDA)
Rapid integrated rural development 150
RE 11, 16, 35, 36, 71, 78, 94, 95, 109–111, 114, 115, 117, 119, 121, 133, 135, 144, 168, 192, 200, 221, 222, 231–233, 237, 242, 243, 268, 281, 286, 288, 290, 299
  applications 29
  development 105
  devices 15, 146, 148, 149, 150
  experts 17
  industry 265
  issues 33
  packages 34
  park 56
  programmes 146
  resources 300
  sources 101, 253, 260, 261, 282
  systems 188
  technologies 15, 150
  technology systems 20
Recycled
  materials 203
  water heating 204
REDA 224
REE 16, 24, 26–30, 33, 69, 71, 72, 79, 103–105, 109, 120, 146, 154, 182–184, 188, 204, 221, 224, 225, 227–229, 231, 233, 245, 263–266, 299
Reference books 22, 48
Regional test centres 197
Religious organizations 91
Renew India web site 229
Renewable energy (*See* RE)
  development 283, 296
  devices 197
  education (*See* REE)
  education policy 31
  education, Bangladesh 69
  engineering 174
  equipment 21, 36
  potential 287
  principles 6
  products 239
  programme 121, 146
  sector 287
  Sources (*See* RES)
  sources, management 78

  sources, utilization 296
  technologies (*See* RETs)
  technology, techno-economic evaluation 21
  training 88, 146
  financing 295
  REPSO-India 106, 125
  RES 33, 34, 43, 50, 59, 81, 146, 149, 228, 232, 234, 250, 252, 263, 275, 277, 284, 285, 289, 287, 295
Research and Development (*See* R&D)
Residential energy conservation 21
Resource conservation 190, 197
RETs 14, 25, 28, 29, 70, 89, 91, 99, 101, 117, 121, 125-127, 146, 228, 229, 246, 263, 283, 287, 289, 295
Rio Conference 1992 43
Roof surface evaporation 282, 346, 347
Rotameters 313, 318
RSE cooling system 348, 349
RSVP (remote sustainable village power) 238
Rural and remote area usage 84
Rural
  areas, 93, 122, 146, 147, 149, 154, 156, 157, 212, 213, 217
  businesses 213
  communication skills 117
  community 89
  development 104, 107, 145
  development programme 149
  electrification 108, 145, 206, 208, 267, 275
  energy 120–122, 124, 127, 147
  needs 146
  planning 122, 123, 125, 129
  programmes 125, 147, 148
  projects 130
  systems 148
  technology 147, 150, 152
  families 157
  households 145, 155
  incomes 157
  India 145
  industrial productivity 145
  problems 115
  sociology 118
  technology 104, 113–115, 117, 119
  technology development 116
  women 149
  work 163
  workers 154, 161
  youth 149

Sailboats 81-83
Sail-propelled ships 81
Satellite cities 93
SBP (Solar Building Programme) 192, 197
Scandinavian countries 34
Scheduled
  castes 150
  tribes 150
Scholarships 12, 18, 152, 167
School of Energy and Environmental Studies (SEES) 329
  of Planning and Architecture 194
  physics 333, 339
  science curriculum 301
  -going children 58, 148
Science and Technology Ministry 309
Science
  education 303
  exhibitions 305
Scientific
  and social attitudes 60, 62
  and technical issues 16
  excellence 17
  knowledge 62, 156
Sea wave power 292
Seasonal storage 45
SEC 146, 195
Second World War 200
Seismic engineering 162
SELCO (solar electric lighting company) 106
Self-employment 149
Semester system 49
Semiconductor 203, 304
Seminar activities 150
Senior secondary
  curriculum 304
  level 74, 75, 303
  school 58
Sewage purification 203
Ship propulsion 81
Short-term education and training 16
Simulations 61
Single-pass forced-flow system 318
Site
  selection 327
  surveying 71
  visits 61
Skill upgrading 147
Skilled human resources 13, 15
Small hydro 105, 146, 291
Small-scale
  energy 90
  energy technologies 35, 36, 91
  hydropower systems 232
  vertical wind turbines 38
Social
  acceptance 76
  housing programmes 155
  responsibilities 19
  science issues 89
Socio-economic
  activities 93
  development 93
  evaluations 90
  structure 115
  totality 59
Software
  packages 229
  tools 195
Solar
  air conditioning 99, 111
  architecture 46, 194
  battery 72

building design principles 197
buildings 190
Buildings Programme (*See* SBP)
buildings workshop 192
candle machines 225
cell manufacturing 112, 180
cells 97, 248, 303, 309
charging system 36
clock 72
collectors 45–47, 64, 67, 78, 308, 309
control devices 158, 162
cooker 28, 40, 59, 72, 95, 100, 106, 139, 141, 142, 174, 225, 249, 301
cooking 139, 140, 248
cooling 46
crop-drying techniques 15
data 308, 310
degasification 33
desalination 21
development 217
devices 249
distillers 95
domestic hot water systems 28
drying 46, 225, 248
education 6
Education Journal 6
electricity 21
energy 6, 40, 43, 47, 49, 69, 71–73, 95, 96, 100, 112, 133, 135, 192, 195, 202, 206, 208, 209, 212, 213, 215, 220, 222, 282, 284, 287, 294, 301, 303, 304, 345
Energy and Sustainable Development 12
Energy Centre (*See* SEC)
energy competition 37, 282
energy conversion 179
energy development 114, 220
energy export industries 46
energy in schools (*See* SOLIS)
energy overview 46
energy R&D 46
Energy Research Centre 43
energy technologies 246, 308
energy training 217
energy utilization 104, 105, 108
Engineer 230, 252, 259, 260
equipment 210
flat plate collector water heating systems 313
gain 161, 162
grill 40
heat collector 202
heat exchangers 35
heaters 202, 301
heating 37, 45, 46, 58, 59, 95, 204, 303
hot water systems 37, 55, 78, 281, 314, 329
house 112
hydrogen 52
irradiance 41
kitchen 35, 40
lighting systems 127, 202
Observatorium, Harestua 334
panels 308
parabolic cooker 133, 135, 136, 140
passive architecture 192, 194, 196
passive buildings 168
photovoltaic 96, 97, 100, 117, 124, 203, 206, 232, 233, 283, 294
photovoltaic energy conversion 247, 309
photovoltaic lanterns 28
ponds 21, 71, 111, 174, 202
power 307
powered houses 96
projects 213
protection 201
radiation 45, 46, 70, 71, 111, 135, 180, 187, 191, 202, 222, 308, 309, 321, 335, 339
  radiation calculation 255
  radiation data 270, 271
  radiation database 270
  radiation model 271
  radiation spectra 307
  reflector 204
  refrigeration 72, 111
  sausage grill 40
  sausage kitchen 40
  spectrum 307
  stills 71, 175
  suppliers 216
  thermal 46, 97, 146, 223, 232
  thermal conversion 247, 308
  thermal devices 180
  thermal installations 45
  thermal laboratory 329
  thermal systems 45, 72, 74, 95, 110, 111, 180, 294
  town planning 112
SolarSizer software 229, 236
Solartools 270
Solenoid
  ball valve 318
  valve flow controller 331
Solid state physics 179
Solid waste treatment 96
SOLIS 281, 333, 335, 337–340, 342
Space
  cooling 201
  heating 201
SPEFC fuel cell 56
SPIC Science Research Foundation, Chennai 56
SPV (*See* Solar photovoltaic)
SS coil/cage 320
Standalone turbines 80, 84
State Council for Science 196
State-level nodal agencies 146
State-of-the-art TLS 61
Steam engine 150
Stirling
engine 39
pump 40
Stress analysis 71
Structural flexibilities 49

Student
  activities 68
  feedback 54
  level 70
  performance 174
  projects 54
  response 171
Sun at Work in Europe (SAWIE) 6
Sun's joules 229, 240
Sunbike project 36, 37
SunDay '98 341, 342, 344
Sustainability, community development 98
Sustainable
  community 95
  construction 201
  development 11, 14, 15, 19, 95, 101, 121, 284, 290, 298
  dissemination 29
  energy 27, 168, 240
  energy planning 107
  family planning 93
  livelihood 59
  power 238
  rural development 148
Swedish Solar Observatory 46
SWOT (strengths, weaknesses, opportunities, and threat) 288
Symposium on Renewable Energy Education 5

Tamil Nadu Energy Development Agency, 194
Tata Energy Research Institute (*See* TERI)
Teacher training courses 6, 60
Teacher's role 58, 60
Teaching
  aids 228, 229, 250
  material 343
  methodologies 48, 51, 57, 118
  programmes 71
  staff 89
Teaching–learning situation 62
  strategies (*See* TLS)
Technical
  cadre 90
  capability 150
  education 115
  manpower 81
  skills 149, 214
  specialists 23
Technician-training facilities 13
Techno-economic analysis 52
Technology assessment 89, 90
Technology transformations 118
Television 229, 246
Temperature gradients 96
TERI 34, 122, 123, 125, 128, 129, 131, 195, 291, 294
Tesla turbine 39
Text selection 48
Textbook 6, 50
Theme festivals 61
Thermal
  comfort 156, 160
  comfort measurement and prediction 197
  comfort quality 155
  conversion 173
  energy 191, 202
  energy storage 21, 180
  load calculations 197
  performances 159, 162
  plants 285
  Science and Energy Systems 181
  storage 71
Thermodynamic problems 39
Thermodynamics 40, 78, 116
Thermonuclear energy 180
Thermostatic control 327
Thermostats 320
Thermosyphon system 313, 316–321, 325, 326, 330
Third World countries 114, 154,155, 159
Tidal
  energy 200
  power 292
  wave 200, 203
TLS 61
Trade and professional associations 22
Trade press 265
Traffic engineering 204
Training 92, 94, 103, 147, 150, 206, 208–210, 213–215, 220
  and education activities 166, 190, 192, 193, 197
  institutions 22
  programme 147–149
  support 214
Transfer and sharing of knowledge 11
Transmission and distribution 145
Transparencies 51
Transportation and environment 199
Trap heat 67
Tree planting 90, 96
Tube–tube heat exchangers 319
Turbine 85
Turbine shaft 39

UGC 176
UK 8
Ulbra (the Lutheran University of Brazil) 267, 268
Ultraviolet measurements 333
UN 11, 15, 18
UN General Assembly Earth Summit 5, 12
Underdeveloped countries 58
Undergraduate levels 72, 75, 77
UNDP 240
UNDP/GEF 88, 291
UNESCO 11, 15, 17–20, 174
UNESCO International Conference on Education 12
UNESCO/ISEEK 22
UNESCO's fundamental commitments 14
UNESCO's learning package 19

United Nations Development Programme (*See* UNDP)
United Nations Educational, Scientific, and Cultural Organization (*See* UNESCO)
United Nations University, Japan 108, 110
University graduates 88
University Grants Commission (*See* UGC)
University libraries 16
University-trained engineers 43
Upper secondary schools 334, 335, 337
Urban
  air pollution 109
  areas 46, 145, 155
  development context 16
  needs 145
US Agency for International Development (*See* USAID)
US Environmental Protection Agency (*See* USEPA)
USA 6–9
USAID 236
USAID/GEF 295
USEPA 109
USSR 8
UV/ozone programme 339

Ventilation 200, 202–204
Vernacular architecture 191
Vibration 71
Video
  cassette 86
  clippings 98
  films 53, 61, 149
  room 100
Villa San Michele 47
Village energy plans 146
Vineyards 157

Wadi-Sudr agriculture cooperative 99
Waste
  recycling 203
  treatment 96
Water
evaporation 345
  pumping 71, 85
  purification 203
  recycling 98
  resources 291
  resources engineering 204
  wells 100
  wheels 301
Wave 29, 96
  energy 69
  power 8, 70
Web sites 57
Weibull distribution 84
West Bengal Renewable Energy Development Agency 194,196
Wind 29, 33, 71, 72, 95, 97, 105, 200, 232, 233, 239, 247
  data 84
  energy 8, 21, 49, 55, 69, 71, 72, 80, 81, 86, 180, 200, 202, 287, 293, 301, 303, 345
  energy course 83
  energy potential 80
  energy technologies 111
  farm 84
  harnessing 96
  machines 71
  power 71, 222, 223, 283
  resources 121
  resources, India 84
  site selection 71
  turbine hardware 86
  turbine industry 86
  turbine sites 86
  turbines 35, 71, 83, 84, 86, 146, 202, 203, 294
  zones 84
Windbreaks 100
Wind-driven mills 81
Windmill, corn grinding 83
Windmills 59, 70, 73, 78, 98, 202, 203, 301
Wing sails 82, 83
Winrock international 236
Workshops 61, 72, 73, 150
World
  Commission on Environment and Development 14
  Federation of Engineering Organizations 15
  Meteorological Organization 84
  Solar Commission 12
  Solar Energy Conference, Budapest 338
  Solar Programme 11
WSP (World Solar Programme 12
World Solar Summit 12
WSSP (World Solar Summit Process) 11, 14, 15
WWW (World Wide Web) 185, 186

Youth unemployment 98

Appendix 1

Programme

Day 1
26 November 1998

0800-1100	**Registration**
0930-1100	**Inaugural Session** Presided over by *Mr P R Dasgupta,* Secretary, Ministry of Human Resource Development, Government of India
0930-0935	Welcome address *Dr R K Pachauri* Director, TERI
0935-0945	Address *Prof. Y D Goswami* Vice-President, IASEE (International Association for Solar Energy Education)
0945-1000	Address *Prof. David Mills* President, ISES (International Solar Energy Society)
1000-1015	Address *Mr P R Dasgupta*
1015-1025	Address *Dr A Ramachandran* President, SESI (Solar Energy Society of India)
1025-1055	Inaugural Address *Prof. S R Hashim* Member Secretary, Planning Commission, Government of India
1055-1100	Vote of thanks *Anil Misra* Organizing Secretary, ISREE-6
1100-1110	**Inauguration of the exhibition**
1110-1140	Tea/Coffee
1140-1255	**Special session of invited lectures** Chairpersons ▪ *Prof. David Mills,* President, ISES ▪ *Dr A Ramachandran,* President, SESI

Rapporteurs
- *Mr Amit Kumar,* TERI
- *Dr S P Mohapatra,* UNESCO

1140-1205 Ten years with the International Association for Solar Energy Education
Lars Broman
Dalarna University, Sweden

1205-1230 Global renewable energy education and training: World solar programme 1996–2005
Boris Berkovski
World Solar Commission, UNESCO

1230-1255 Trends and issues in renewable energy education
H P Garg
IIT-D (Indian Institute of Technology, New Delhi)

1255-1410 Lunch

1410-1600 ***Session IA***
Renewable Energy education policy/Curriculum design/Case studies

Chairperson
- *Prof. H P Garg,* IIT-D

Rapporteurs
- *Dr P Venkataraman,* TERI
- *Dr T C Kandpal,* IIT-D

1410-1500 Renewable energy for a clean environment – Education is the key to implementation
Y D Goswami
University of Florida, USA

1500-1530 The role of the ISES in promoting the use of renewable energy (Solar Cities Project)
David Mills
University of Sydney, Australia; President, ISES

1530-1600 Renewable energy in university physics teaching
Arne Auen Grimnes
Agricultural University of Norway, Aas

1600-1630 Tea/Coffee

1630-1800 ***Session I B***
Renewable energy education policy/Curriculum design/Case studies

Chairpersons
- *Prof. A N Rao,* Anna University, Chennai
- *Prof. M A Rashid Sarkar,* Bangladesh University of Engineering and Technology, Dhaka

Rapporteurs
- *Mr N S Prasad,* TERI
- *Mr Dilip Singh,* TERI

1630-1700 Creating a European Solar Engineering School
Lars Broman
Dalarna University, Sweden
1700-1720 Impact-oriented comprehensive approach for energy education
Jyotirmay Mathur
IIT-D
1720-1750 Design and teaching of a course on renewable energy at Birla Institute of Technology and Science, Pilani
M Ramachandran
BITS, Pilani
1750-1815 Designing packages for renewable energy education
Anitha Saravanan
TERI, India

1410-1800 ***Parallel session***
Workshop
Demonstration of multimedia packages and videos
Experiments on renewable energy devices

Day 2
27 November 1998

0900-1100 ***Joint Session I***
Vocationalization of renewable energy education/Training and awareness programmes

Chairpersons
- *Dr Shyamala Abeyratne,* Winrock Internationa-India
- *Dr VVN Kishore,* TERI

Rapporteur
- *Ms Pamposh Bhat,* Asian and Pacific Centre for Transfer of Technology, New Delhi

0900-0925 Training programme on solar energy utilization
R Saravanan
Anna University, Chennai
0925-0950 Capacity building for renewable energy development
Shyamala Abeyratne
Winrock International, India
0950-1010 Syllabus design of rural technology course for technician diploma in mechanical engineering in Nepal
Ridhi Ratna Sthapit
Thapathali Campus, Kathmandu
1010-1030 Energy education and capacity building of NGOs: TERI's experience
Shirish Sinha and Dilip Singh
TERI

1030-1050 Teaching and training communities of Kathmandu Valley on the use of solar parabolic cookers
Sama Shrestha
Centre for Rural Technology, Kathmandu

1050-1110 Renewable energy education and training for integrated rural development
Subodh Kumar
Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development, New Delhi

1110-1130 Tea/Coffee

1130-1330 ***Joint Session II***

Miscellaneous topics

Chairpersons
- *Prof. M A R Akhanda,* BUET, Dhaka
- *Dr E V R Sastry,* MNES, Government of India

Rapporteurs
- *Mr Pradeep Dadhich,* TERI
- *Dr G Datta,* University of Delhi

1130-1150 Physics with energy studies specialization: an experience
S K Samdarshi
North Maharashtra University, Jalgaon

1150-1210 Use of the Internet in renewable energy education
Joachim Goettsche
University of Zimbabwe

1210-1230 Training and education activities on solar buildings in India
Bibek Bandyopadhyay
MNES, Government of India

1230-1250 Curriculum of a B. E. Civil Engineering course on renewable energy
Dulal Goldar
Delhi College of Engineering, New Delhi

1250-1310 Renewable energy in product design education: a perspective
Praveen Nahar
IIT-D

1310-1330 Operational strategies of INFORSE
Lalita Balakrishnan and Meenu Mishra
All India Women's Conference, New Delhi

1330-1430 Lunch

1430-1545 ***Session II***

Media and advanced electronic technologies in the promotion of renewable energy education

Chairpersons
- *Prof. R L Sawhney,* Devi Ahilya University, Indore
- *Dr Shahida Rafique,* University of Dhaka

Rapporteurs
- *Dr Jai Prakash,* University of Delhi
- *Mr Shirish Sinha,* TERI

1430-1500 Electronic communication technologies for renewable energy education
Christopher Gronbeck
Center for Renewable Energy Sustainabl Technology, Washington DC

1500-1515 Education television as a medium for renewable energy technology propagation
D Mutharasu
Thiagarajar College of Engineering, Madurai

1515-1530 Teaching aids for lectures on renewable energy sources – an example from Slovenia
Sašo Medved
University of Ljubljana, Slovenia

1530-1545 Press as a development tool in publicizing renewable energy education and knowledge
S Ganesh
Freelance journalist

1545-1600 Awards distribution ceremony

1600-1630 Tea/Coffee

1630-1800 ***Valedictory Session***
Chairperson
- *Dr A Ramachandran,* President, SESI

1630-1700 Session summaries by the rapporteurs
1700-1800 Panel discussion
Panelists
- *Dr R K Pachauri*
- *Dr David Mills*
- *Prof. Yogi D Goswami*
- *Dr V Bakthavatsalam*
- *Mr Rakesh Bakshi*
- *Prof. H P Garg*

Moderator
- *Dr Ajay Mathur*

1800 Closing of the Symposium

1430-1800 ***Parallel session***
Workshop
Demonstration of multimedia packages and videos
Experiments on renewable energy devices

Day 3
28 November 1998

0930-1100	***Session I A*** **Renewable energy education in schools and colleges** ▪ Chairperson *Dr T C Tripathi,* Solar Energy Centre, MNES ▪ Rapporteur *Dr Ashvini Kumar,* Solar Energy Centre, MNES
0930-1000	India's leadership in renewable energy education for sustainable development *B S K Naidu* Rural Electrification Corporation
1000-1030	Renewable energy education in school science curriculum *R D Shukla* NCERT
1030-1100	Education of solar radiation and renewable energy technologies at the University of Dhaka *Dr Shahida Rafique* University of Dhaka, Bangladesh
1100-1130	Tea/Coffee
1130-1320	***Session I B*** **Renewable energy education in schools and colleges** ▪ Chairperson *Dr A K Dahiya,* Director, Mahatma Gandhi Institute of Integrated Rural Energy Planning and Development, New Delhi ▪ Rapporteur *Ms Sama Shrestha,* Centre for Rural Technology, Kathmandu
1130-1200	Solar water heating systems designed and developed for training and demonstration *R L Sawhney* Devi Ahilya University
1200-1230	SOLIS: Solar energy in schools *Karl Torstein Hetland* Dalen vidaregäande skola, Norway
1230-1300	Solar energy competition *Einar Oterholm* Dalen vidaregäande skola, Norway
1300-1320	Evaporative cooling of buildings in hot regions *S P Jain* University of Roorkee, Roorkee
1320-1400	Lunch
1400-1630	***Workshop*** Demonstration of multimedia packages and videos Experiments on renewable energy devices

Appendix 2

List of authors

Renewable energy education: current scenario and future projections
pp. 369-370

Prof. M A R Akhanda
Bangladesh University of Engineering and Technology
Dhaka 1000, Bangladesh
E-mail razzaq@me.buet.efu

Mr Salah Arafa
The American University in Cairo
Cairo, Egypt
E-mail smarafa@aucegypt.edu

Dr Bibek Bandyopadhyay
Ministry of Non-conventional Energy Sources
Block 14, C G O Complex
Lodhi Road
New Delhi 110 003
Tel. 436 0331
Fax 436 1298

Mr Boris Berkovski
World Solar Commission
Engineering and Technology Division, UNESCO
1 Ruo Miollis, 75732 Paris
Cedex 15 France

Prof. Lars Broman
University College of Dalarna
Sweden
Tel. 49 421 13718
Fax 49 421 1655323

Mr S Ganesh
1769, Lodi Road Complex
New Delhi 110 003
Tel. 460 4754

Prof. H P Garg
Centre for Energy Studies
Indian Institute of Technology
New Delhi 110 016
Tel. 91 11 462 2246
E-mail hpgarg@ces.iidt.ernet.in

Dr Joachim Goettsche
Renewable Energy Programme
Faculty of Engineering University of Zimbabwe
P O Box MP 167, Harare
Zimbabwe
Tel. 263 4 303 211 Ext 1403/1380
Fax 263 4 303 280, 333 674
E-mail gottsche@zimbix.uz.zw

Prof. Kunal Ghosh
Aerospace Engineering
Indian Institute of Technology
Kanpur 208 016
E-mail kunal@iitk.ernet.in

Prof. Dulal Goldar
Dept. of Civil Engg.,
Delhi College of Engineering
Kashmiri Gate
Delhi 110 006
Tel. 296 8140
E-mail Dgoldar@doe.ernet.in

Mr Arne Auen Grimnes
Agricultural University of Norway
POB 5065 N-1432 AAS
Norway
Tel. 47649487
Fax 4766498
E-mail arne.grimnes@itf.nlh.no

Mr Christopher Gronbeck
Center for Renewable Energy Sustainable Technology, Director of Software Development
1020 NE 68th Street,
Seattle, WA 98115
USA
Tel. 01225312391
Fax 01225312561
E-mail ceg@crest.org

Mr Karl Torstein Hetland
Dalen vidaregäande skole,
3880 Dalen
Norway
E-mail karlth@dalen.vgs.no
Tel. 47 35077271
Fax 47 35077206

Prof. S P Jain
Director & Adviser
University of Roorkee
80/2 Civil Lines
Roorkee 247 667
Tel. 0133 274401

Dr Subodh Kumar
Centre for Energy Studies
Indian Institute of Technology
Hauz Khas
New Delhi 110 016
Tel. 66 6979
Fax 686 2037

Dr Jyotirmay Mathur
Centre for Energy Studies
Indian Institute of Technology, Hauz Khas
New Delhi 110 016
Tel. 66 6979
Fax 686 2037

Mr Saso Medved
University of Ljubljana
Slovenia
Fax 386 61 218 567
E-mail saso.medved@fs.uni.lj.si

Mr Jorge Mitchell
CRICYT-Mendoza
P O Box 131 (5500)
Mendoza
Argentina
E-mail jmitchel@lab.cricyt.edu.ar

Dr D Mutharasu
Thiagarajan College of Engineering
Madurai
Tamil Nadu 625 015
E-mail Pcsmadurai@vsnl.com

Dr N M Nahar
Central Arid Zone Research Institute
Jodhpur 342 003
Tel. 0291 740386
Fax 0291 740706

Dr B S K Naidu
Rural Electrification Corporation
Scope Complex
Lodhi Road
New Delhi 110 003
Tel. 436 1320
Fax 461 0461
E-mail rec.rural@axcess.net.in

Mr Einar Oterholm
Ressurssentereti Tinguoll
N-6680 Halsanavstan
Norway
Tel. 47 35077271
Fax 47 35077206
E-mail einer.oterholm@eunet.no

Dr Shahida Rafique
Chairman, Department of Applied Physics and Electronics, University of Dhaka, Bangladesh
Tel. 880 2 505732
Fax 880 2 865583

Prof. M Ramachandran
Coordinator, CREED
Birla Institute of Technology and Science
Pilani, Rajasthan 333 031
Tel. 01596 42126
Fax 01596 42184

Prof. S K Samdarshi
School of Physical Sciences
North Maharashtra University
P B No 80 Jalgaon 425 001
Tel. 0257 222 187
Fax 0257 222 183

Mr J C Vernetti dos Santos
Lutheran University of Brazil
Rua Miguel Tostes 101
92420-280 Canoas
Brazil
Tel. 51 477 6298
Fax 51 477 1313
E-mail vernetti@mozart.ulbra.tche.br

Ms Anitha Saravanan
Tata Energy Research Institute
Darbari Seth Block
India Habitat Centre
Lodhi Road
New Delhi 110 003
Tel. 460 1550, 462 2246
Fax 462 1770, 463 2609
E-mail anithas@teri.res.in

Mr R Saravanan
Anna University
CNRSE Mechanical Engg.
Sardar Patel Road
Chennai 160 025
Tel. 044 491 2027

Prof. R L Sawhney
School of Energy & Environmental Studies
Devi Ahilya University
Indore
Tel. 0731 462 366
Fax 0731 76318

Mr Sama Shrestha
Programme Officer
Center for Rural Technology
P O Box 3628
Tripureeswore
Kathmandu, Nepal
Tel. 977 1 246 465
Fax 977 1 246 307

Prof. R D Shukla
National Council of Education Research and Training
Sri Aurobindo Marg
New Delhi 110 016
Tel. 651 9154, 696 4712
Fax 686 8419

Mr Shirish Sinha
Tata Energy Research Institute
Darbari Seth Block
India Habitat Centre
Lodhi Road
New Delhi 110 003
Tel. 460 1550, 462 2246
Fax 462 1770, 463 2609
E-mail shirish@teri.res.in

Mr Riddhi Ratna Sthapit
Thapathali Campus
P O Box 280, Ramshahpath
Kathmandu, Nepal
Tel. 977 1 246465
Fax 977 1 246307

Mr Herbert A Wade
Naresuan University
Phitsanulok 65000
Thailand
E-mail herbwade@compuserve.com

Appendix 3

List of participants

Renewable energy education: current scenario and future projections
pp. 371-378

Mr Arif Abbas
RRB Vestas
161, Sukhdev Vihar
New Delhi
Tel. 683 8365, 684 8228
Fax 683 5160
E-mail vvrb@gnmds.
globalnetems.vsnl.net.in

Dr Shyamala Abeyratne
Country Director
Winrock International
7, Poorvi Marg
New Delhi 110 007
Tel. 614 2965
Fax 614 6004
E-mail winrock-
delhi@cgnet.com

Dr J H Agarwal
Vice President
Institution of Electronics
and Telecommunications
Engineers
G-83, Krishinagar Adhartal
P O Jabalpur 482 004
Madhya Pradesh
Tel. 0761 344 400

Dr S K Agarwal
B-6 MNR Engineering
College
Allahabad 211 004
Uttar Pradesh
Tel. 0532 540 227
Fax 0532 642 436, 640 770

Mr Maurice Roger Alarie
Partners in Rural Development
323 Chapel, Ottawa
KIN 722 Canada
Tel. 613 237 0180
Fax 613 277 5969
E-mail maurie@partners.ca

Mr S L Arora
House No. 40, Ward 9
Faridabad (Old) 121 002
Haryana

Dr S Arumugam
Department of Physics
Gandhigram Rural Institute
Gandhigram 624 303
Tamil Nadu

Mr Rakesh Bakshi
RRB Vestas
161, Sukhdev Vihar
New Delhi
Tel. 683 8365, 684 8228
Fax 683 5160
E-mail vvrb@gnmds.
globalnetems.vsnl.
net.in

Ms Lalita Balakrishnan
Chairperson
Rural Energy Department
All India Women's
Commission
6, Bhagwan Dass Road
New Delhi 110 001
Tel. 338 9680
Fax 338 4092
E-mail aiwcete@nda.
vsnl.net.in

Dr Bibek Bandyopadhyay
Ministry of Non-conventional Energy Sources
Block 14, C G O Complex
Lodhi Road
New Delhi 110 003
Tel. 436 0331
Fax 436 1298

Mr Bennet Benjamin
Honorary Director
Centre for Rural Health and
Social Education
A-11, Ashok Nagar
Tirupattur 635 601
Tel. 041 792 0042
Fax 041 792 0824

Dr M Bhandari
Indian Institute of Technology
Hauz Khas
New Delhi
Tel. 686 1977
Fax 686 2037
E-mail tarak@ces.iitd
.ernet.in

Ms Pamposh S Bhat
APCTT, P O Box 4575
Off New Mehrauli Road
New Delhi 110 016
Tel 696 6509, 685 6276
Fax 685 6274

Prof. Lars Broman
University College of Dalarna
Sweden
Tel. 49 421 13718
Fax 49 421 1655323

Dr S S Chandel
Principal Scientific Officer
State Council of Science,
Technology & Environment
B-34 SDA Complex

Kusumpati
Shimla 171 009
Himachal Pradesh
Tel. 0177 222 490
Fax 0177 220 998

Dr Ram Chandra
Indira Gandhi National
Open University
Regional Services Division
Maidan Garhi
New Delhi 110 016
Tel. 686 2063
Fax 686 7063

Mr R K Chaudhary
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Ms Sheetal Chhabra
SREI International Finance Ltd
Corporate Finance,
Atmaram House
New Delhi
Tel. 91 11 332 2274/90
Fax 91 11 373 1542
E-mail jainsheetal@
hotmail.com

Dr A K Dahiya
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Dr G Datta
Deshbandhu College
University of Delhi
Kalkaji, New Delhi 110 019

Ms Prava Debal
Deputy Manager
Indian Renewable Energy
Development Agency
Limited
Core 4-A
East Court, 1st Floor
Indian Habitat Centre
Lodhi Road
New Delhi 110 003
Tel. 460 1344, 464 2367

Mr Venkataraman Gajula
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Mr Mukesh Kumar Gandhi
Delhi Public School
Meerut Road
Ghaziabad 201 001

Mr S Ganesh
1769, Lodi Road Complex
New Delhi 110 003
Tel. 460 4754

Prof. H P Garg
Centre for Energy Studies
Indian Institute of Technology
New Delhi 110 016
Tel. 91 11 462 2246
E-mail hpgarg@ces.
iidt.ernet.in

Mr Uday Singh Gautam
KLCE Cares
Centre for Alternate and
Renewable Energy
Sources
Near Kandhari Lane
Vijaywada 520 010
Tel. 0866 411 991
E-mail gautam_us@
hotmail.com

Dr Joachim Goettsche
Renewable Energy
Programme
Faculty of Engineering
University of Zimbabwe
P O Box MP 167, Harare
Zimbabwe
Tel. 263 4 303 211
Fax 263 4 303 280, 333 674
E-mail gottsche@
zimbix.uz.zw

Prof. Dulal Goldar
Dept. of Civil Engg.,
Delhi College of Engineering
Kashmiri Gate
Delhi 110 006
Tel. 296 8140
E-mail Dgoldar@doe.ernet.in

Prof. Yogi D Goswami
University of Florida
P O Box 116300
MEB 237, Gainsville
Florida 326 B6300
Tel. 003523920812
Fax 00323921071
E-mail Solar@cimar.me.
ufl.edu

Mr Arne Auen Grimnes
Agricultural University of
Norway
P O Box 5065 N-1432
Aas, Norway
E-mail arne.grimnes@
itf.nlh.no

Mr Christopher Gronbeck
Center for Renewable
Energy Sustainable
Technology
1020 NE 68th Street
Seattle, WA 98115 USA
Tel. 01 225 312391
Fax 01 225 312561
E-mail ceg@crest.org

Mr R K Gupta
Solar Thermal Group
Central Electronics Ltd.
Sahibabad 201 010
Uttar Pradesh
Tel. 91 771 640
Fax 91 771 843

Mr Rajkumar Gupta
Energy Research Centre
Punjab University
Chandigarh
Tel. 0172 541 944

Mr Karl Torstein Hetland
Dalen vidaregäande Skole
3880 Dalen, Norway
E-mail karlth@dalen.vgs.no
Tel. 47 35077271
Fax 4735077206

Mr S K Hussaini
Wheel & Axle Plant
Yelahanka, Bangalore 560 064
Tel. 846 0340
Fax 080 846 0367

Mr Sanjeev Jain
Executive Engineer
M P Urja Vikas Nigam Ltd
H 1108, New Darpan Colony
Gwalior
Madhya Pradesh
Tel. 0751 345 750
Fax 0751 341 608

Prof. S P Jain
Centre Research Development Education Cum
Training And Technology-Upgradation of Renewable Energy Systems of Cooling in Tropics
80/2 Civil Lines
Roorkee 247 667
Tel. 01332 74401

Mr Virendra Jain
Energy Saver Associates
Infront Hotel Gonalika
Jayendragunj
Gwalior
Tel. 0751 320 705/001
Fax 0751 320 705

Mr S K Jain
O-7, Hospital Road Jaipur
Tel. 0141 363 487
Fax 0141 383 978

Mr R Jayaprakash
Department of Physics
SRMV College of Arts of Science
SRKV POST
Coimbatore 641 020
Tel. 0422 892 461
Fax 0422 892 582

Prof. S K Joshi
Workshop Dept
Maharashtra Institute of Technology
124, Paud Road Kothrud
Pune 411 038
Tel. 0212 332 767, 331 795
Fax 0212 342 770

Prof. S C Vasideo Joshi
Vishwakarma Institute of Technology Mechanical Engineering
666 Uin Bibwewadi, Pune
Tel. 0212 512 294, 515 594
Fax 0212 515 926
E-mail prinvit@giaspn.fie.l vsnl.net.in

Dr Chand K Jotshi
Thapar Institute of Engg & Tech
Chemical Engineering
Patiala 147 001
Tel. 0175 393 063
E-mail ckj@tietp.ren.nic.in

Prof. Manmohan S Kalra
Indian Agril Research Institute
Agricultural Engineering
New Delhi 110 024
Tel. 578 5594

Dr T C Kandpal
Centre for Energy Studies
Indian Institute of Technology
Hauz Khas
New Delhi 110 016
Tel. 686 1977
Fax 686 2037
E-mail tarak@ces.iitd.ernet.in

Mr Shriram Gopal Kanitkar
Walchand College of Engineering
Vishrambagh
Sangli 416 415
Tel. 0233 300 383
Fax 0233 30031

Dr S C Kaushik
Centre for Energy Studies
Indian Institute of Technology
Hauz Khas
New Delhi 110 016
Tel. 686 1977

Mr Mahesh Kaushik
Mahatama Gandhi Institute of Integrated Rural Energy Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029-33
Fax 720 1033, 720 1540

Mr Shitij Kaushik
Sr Engineer-Marketing
Tata B P Solar India Ltd.
F-27/4
Okhla Industrial Area
Phase- II
New Delhi 110 020
Fax 683 9726/754

Mr N D Kaushika
Professor
Centre for Energy Studies
IIT Delhi 110 016
Tel. 6861977
Fax 6862037

Dr J P Kesari
Mahatama Gandhi Institute of Integrated Rural Energy Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029-33
Fax 720 1033, 720 1540

Mr Niranjan Khatri
Landbase India Ltd

13 Basant Lok Vasant Vihar
New Delhi 110 021
Tel. 614 3452

Ms Anita Khullar
Winrock International
7, Poorvi Marg
New Delhi 110 007
Tel. 614 2965
Fax 614 6004
E-mail winrock-delhi@
cgnet.com

Dr V V N Kishore
TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi 110 003
Tel. 460 1550, 462 2246
Fax 462 1770, 463 2609
E-mail vvnk@teri.res.in

Prof. Balot Kulnazarov
The Osh Resource Center of
Soros Foundation
Kurnamjan Datka Street 271
City of Osh, 214000
Kyrgyzstan
Telfax 33222 57326
E-mail bolot@elcat.osh.su

Dr A P Kulshrestha
Ministry of Science &
Technology
Government of India
Technology Bhavan New
Mehrauli Road New Delhi
Tel. 686 2503
Fax 686 2418, 686 3847
E-mail apk@alpha.nic.in

Mr Sanjeev Kumar
C/o Dr. G N Tiwari
Indian Institute of Technology
Hauz Khas
New Delhi 110 016
Tel. 686 1977, ext. 5040
Fax 686 2037
E-mail gntiwari@ces.iit
.ernet.in

Dr Subodh Kumar
Centre for Energy Studies
Indian Institute of Technology
Hauz Khas
New Delhi 110 016
Tel. 66 6979
Fax 686 2037

Mr Harish Kumar
Technology Assessment
Group
49/244/1, Tapah Taniya
Rung Bharian Gali
Sarafa Bazar Alwarm
Rajasthan 301 001
Tel. 0143 13396

Mr Naveen Kumar
Delhi College of Engineering
Bawana Road
Delhi 110 042

Mr Atam Kumar
School of Energy & Environmental Studies
Devi Ahilya University
Indore
Tel. 0731 462366
Fax 0731 76318

Mr Ajay Kumar
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 7201540

Mr Awdesh Kumar
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029-33
Fax 720 1033, 720 1540

Mr Jayant Kumar
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Mr Sarvesh Kumar
RRB Vestas
161, Sukhdev Vihar
New Delhi
Tel. 683 8365, 684 8228
Fax 683 5160
E-mail vvrb@gnmds
.globalnetems
.vsnl.net.in

Dr Ashwini Kumar
Solar Energy Centre (MNES)
Gual Pahari
Gurgaon
Tel. 91 1243 79207
Fax 91 011 436 1298
E-mail sec@x400
.nicgw.nic.in

Mr Pankaj Kumar
Solar Energy Centre
Gual Pahari
Gurgaon
Tel. 91 1243 79207
Fax 91 011 436 1298
E-mail sec@x400
.nicgw.nic.in

Mr Lalmoni
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 7201540

Dr Vidyu Lata
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Dr Rajeshwari Madhavan
Reader, Department of
Botany Daulat Ram College
University of Delhi
Delhi 110 007
Tel. 725 7863

Mr Kumar Mahendra
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Mr Mahesh
Tata BP Solar Pvt Ltd
Plot no. 72 Electronic City
Hosur Road
Banglore
Tel. 080 852 0082/83,
852 1016/17/18
Fax 080 852 0972/116
E-mail tbp.mkt@tatbp
.sprintrpg.ems
.vsnl.net.in

Mr Neelam Pari Malkani
Department of Botany
Daulat Ram College
University of Delhi
4, Patel Marg
New Delhi 110 007
Tel. 725 7863

Dr Jyotirmay Mathur
Centre for Energy Studies
Indian Institute of Technology
Hauz Khas
New Delhi 110 016
Tel. 66 6979
Fax 686 2037

Mr Saso Medved
University of Ljubljiana
Slovenia
Fax 386 61 218 567
E-mail saso.medved@
fs.uni.lj.si

Mr S K Meshram
Deputy Manager
Indian Renewable Energy
Development Agency
Limited
Core 4-A
East Court, 1st Floor
Indian Habitat Centre
Lodi Road
New Delhi 110 003
Tel. 460 1344, 464 2367

Dr David Mills
School of Physics, A28
University of Sydney
New South Wales 2006
Australia
Tel. 0061299242016,
94165393
Fax 006129942016
E-mail d.mills@physics
.usyd.edu.au

Ms Meenu Mishra
Chair-Person
Rural Energy Department
AIWC, 6 Bhagwan Dass Road
New Delhi 110 001
Tel. 338 9680
Fax 338 4092
E-mail aiwcetc@nda
.vsnl.net.in

Mr Devi Prasad Mishra
Mahatama Gandhi Institute of
Integrated Rural Energy
Planning & Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Dr S P Mohapatra
UNESCO
Unesco House
8, Poorvi Marg Vasant Marg
New Delhi 110 057
Tel. 614 7310, 614 6308,
614 6285, 614 6588,
614 1437, 614 0038–39
Fax 91 11 614 3351,
6142714
E-mail in:unesco.newdelhi@
unesco.org

Ms Swati Munshi
Regional Research Laboratory
Chemical Engineering
Jorhat 785 006
Tel. 0376 320 692
Fax 632 1158

Dr D Mutharasu
Lecturer in Physics
Thiagarajan College of
Engineering
Madurai
Tamil Nadu 625 015
E-mail Pcsmadurai@
vsnl.com

Mr S R K Venkata Naga
K L College of Engineering
Centre for Alternate
Renewable Energy Sources
Kandhar
Vijaywada 520 010

Dr N M Nahar
Central Arid Zone Research
Institute
Jodhpur 342 003
Tel. 0291 740386
Fax 0291 740706

Dr Praveen Nahar
Indian Institute of Technology
Powai Mumbai 400 076
Tel. 022 782 575,
022 578 3480
Fax 022 578 83480
E-mail pnahar@
ide.iitb.ernet.in

Dr B S K Naidu
Rural Electrification
Corporation
Scope Complex
Lodhi Road
New Delhi 110 003

Tel. 436 1320
Fax 461 0461
E-mail rec.rural@
axcess.net.in

Dr Kanan Nanda
Senior Reader Department
of Botany
Daulat Ram College
University of Delhi
New Delhi 110 007
Tel. 723 3050
Fax 746 4718

Dr B S Negi
Solar Energy Centre
Gual Pahari
Gurgaon
Tel. 91 1243 79207
Fax 91 011 436 1298
E-mail sec@x400
.nicgw.nic.in

Mr Einar Oterholm
Ressurssentereti Tinguoll
N-6680 Halsanavstan
Norway
Tel. 47 35077271
Fax 47 35077206
E-mail einer.oterholm@
eunet.no

Dr R Palakurty
Mahatama Gandhi Institute
of Integrated Rural
Energy Planning &
Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029-33
Fax 720 1033, 720 1540

Mr P K Parida
Mahatama Gandhi Institute
of Integrated Rural
Energy Planning &
Development
Bakoli, Alipur
Delhi 110 036
Tel. 720 1029–33
Fax 720 1033, 720 1540

Dr Rama Pasricha
Botany Deptartment
Daulat Ram College
New Delhi 110 009
Tel. 98110 20433

Mr Mark Paul
Action for Food Production
Technology & Innovative
Programme
25/1A, Instt. Area, Janakpuri
New Delhi 110 058
Tel. 0091 11 555 3652

Mr S D Pohekar
College of Engineering
Sahajanand Nagar
Kopargaon 423 603
Maharashtra

Mr V Ponnuswamy
Department of Physics
SRMV College of Arts of
Science
SRKV POST
Coimbatore 641 020
Tel. 042 289 2461
Fax 042 289 2582

Dr Gayatri Prakash
Reader in Zoology
Daulat Ram College
University of Delhi
New Delhi 110 007
Tel. 723 3050
Fax 746 4718

Dr Shahida Rafique
Chairman
Department of Applied
Physics and Electronics
University of Dhaka
Bangladesh
Tel. 880 2 505732
Fax 880 2 865583

Dr A Ramachandran
President SESI Tata Energy
Research Institute
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi 110 003
Tel. 460 1550, 462 2246
Fax 462 1770, 463 2609

Prof M Ramachandran
Coordinator, CREED
Birla Institute of Technology
& Science
Pilani
Rajasthan 333 031
Tel. 01596 42126
Fax 01596 42184

Mr P Venkata Ramana
Tata Energy Research Institute
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi 110 003
Tel. 460 1550, 462 2246
Fax 462 1770, 463 2609

Prof. A N Rao
Anna University
CNRSE Mechanical
Engineering
Sardar Patel Road
Chennai 160 025
Tel. 044 491 2027

Dr M A R Akhanda
Bangladesh University of
Engineering & Technology
Dhaka 1000
Bangladesh
Fax 880 2 863 046/026
E-mail razzaq@me.buet.edu.

Mr Shafiqur Rehman
Box No. 767
Dhahran 31261
Saudi Arabia
Tel. 0096638606129
Fax 0096638602215
E-mail Srehman@kfupm.
edu.sa

Mr C K Rohatgi
Rohitas Electronics
Opp. Civil Courts

Civil Lines
Kanpur 208 001
Tel. 311 223
Fax 314 546

Dr Dilip Samantaray
P O Baramba
Post Box 1
Cuttack 754 031
Orissa
Tel. 067 213 276

Prof. S K Samdarshi
School of Physical Sciences
North Maharashtra University
P B No 80
Jalgaon 425 001
Maharashtra
Tel. 0257 222 187
Fax 0257 222 183

Mr R Saravanan
Project Engineer, CNRSE
Anna University
Chennai 600 025
Tel. 230 0121
Fax 230 0875

Dr M A Rashid Sarkar
Bangladesh University of Engineering & Technology
Dhaka 1000
Bangladesh
Fax 863046/863026
E-mail Rashid@
melouet.edu

Ms Anitha Saravanan
TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi 110 003
Tel. 460 1550, 462 2246
Fax 462 1770, 463 2609
E-mail anithas@teri.res.in

Prof. R L Sawhney
School of Energy & Environmental Studies
Devi Ahilya University
Indore
Tel. 0731 462 366
Fax 0731 76318

Mr Anil Sharma
Rail Coach Factory
Kapurthala 144 602
Tel. 0181 58356/357/55141
Fax 0181 57091

Ms Ruth Shija
SONET
Box 77279 Dar es Salaam
Tanzania
E-mail sonet@twiga.com

Mr Sama Shrestha
Centre for Rural Technology
P O Box 3628
Tripureeswore
Kathmandu, Nepal
Tel. 977 1 246 465
Fax 977 1 246 307

Dr A R Shukla
Ministry of Non-conventional Energy Source
Block 14 CGO Complex
Lodhi Road
New Delhi 110 003
Tel. 436 1604
Fax 436 1604

Prof. R D Shukla
National Council of Education Research and Training
Sri Aurobindo Marg
New Delhi 110 016
Tel. 651 9154/ 696 4712
Fax 686 8419

Mr J Singh
Sah Industrial Research Institute
Sarnath, Varanasi
Uttar Pradesh
Tel. 38539

Mr Param Pal Singh
School of Energy Studies for Agriculture
Punjab Agricultural University
Ludhiana
Tel. 278 405 655
Fax 278 400 945

Mr Anup Singh
Vice Chancellor
Punjab Technical University
Jalandhar 144 011
Tel. 0181 290 079, 297 046
Fax 0181 290 079

Mr Shirish Sinha
TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi 110 003
Tel. 460 1550, 462 2246
Fax 462 1770, 463 2609
E-mail shirish@teri.res.in

Ms Ira Sinha
Sri Aurobaindo College
Zoology Department
Malviya Nagar
New Delhi 110 052
Tel. 7430263

Ms Tripta Sondhi
UNESCO
Unesco House
8, Poorvi Marg
Vasant Marg
New Delhi 110 057
Tel. 614 7310, 614 6308
Fax 614 3351
E-mail in:unesco.newdelhi
@unesco.org

Dr C E Sooriamoorthy
Department of Solar Energy
Madurai 625 015
Tamil Nadu

Mr Ved Prakash Srivastava
NCERT
Aurobindo Marg
New Delhi
Tel. 651 9154, 696 4712
Fax 686 8419

Mr Riddhi Ratna Sthapit
Thapathali Campus
P O Box 280, Ramshahpath
Kathmandu, Nepal
Tel. 977 1 246465
Fax 977 1 246307

Mr Kant Prasad Thanvi
Central Arid Zone Research Institute
Jodhpur
Tel. 0291 740386
Fax 0291 740706

Dr T C Tripathy
Solar Energy Centre
Gual Pahari
Gurgaon
Tel. 91 1243 79207
Fax 91 011 4361298
E-mail sec@x400.nicgw.nic.in

Dr Vibha Vashisht
CENDORT
36A, Rural Development
Rohini, New Delhi
Tel. 726 5191
Fax 555 1096

Mr R K Vimal
Deputy Manager
Indian Renewable Energy Development Agency Ltd
Core 4-A, East Court
1st Floor
Habitat Place
Lodhi Road
New Delhi 110 003
Tel. 460 1344, 464 2367

Appendix 4

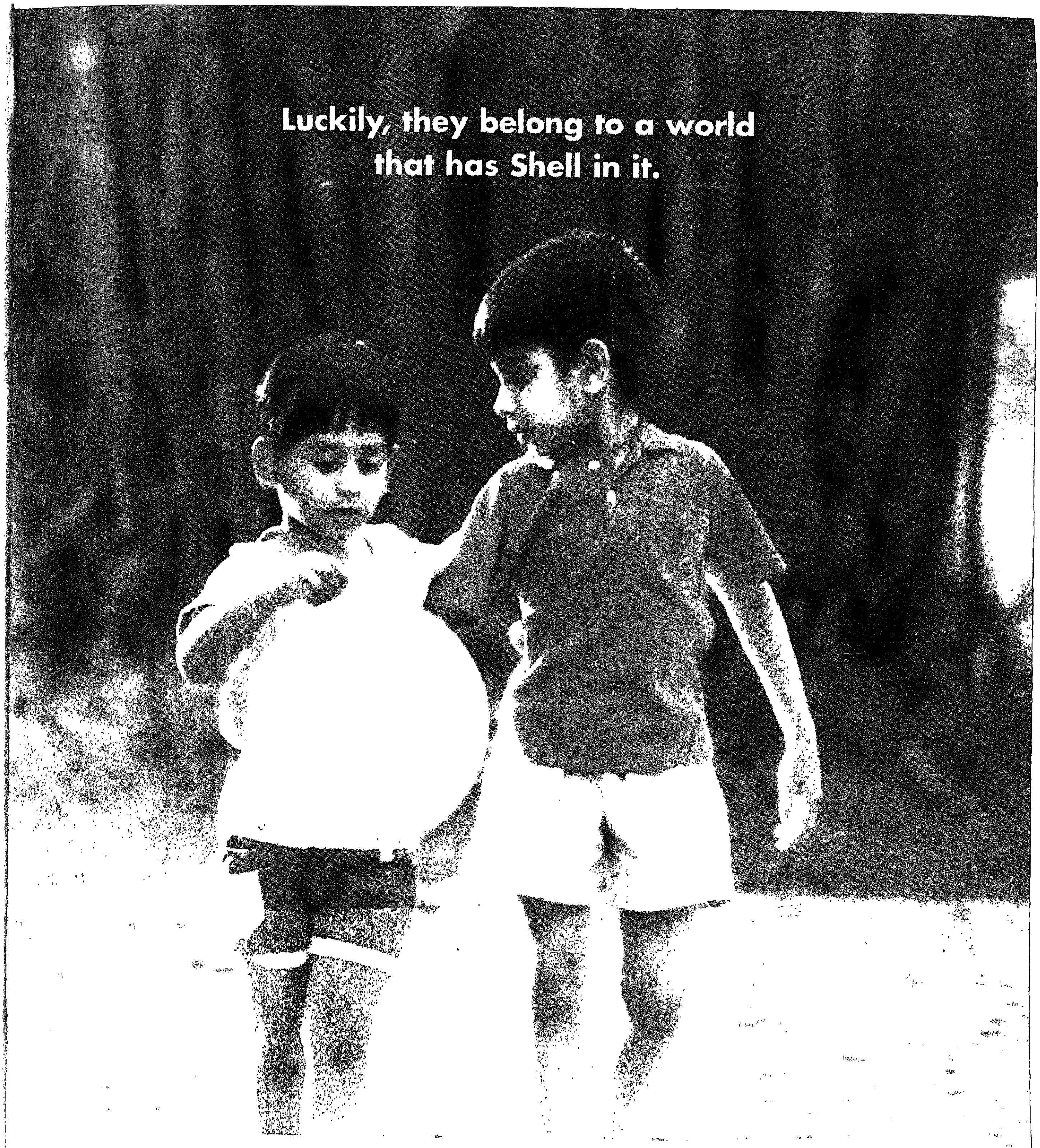
List of participants from schools/colleges

Renewable energy education: current scenario and future projections
pp. 379-381

School	Teacher(s)	Students(s)
Blue Bells International School Kailash Colony New Delhi – 110 048	Ms Veena Suri	Ms Bhavana Hariharan Ms Jaspreet Kaur
Cambridge School Ring Road, Srinivaspuri New Delhi – 110 065	Ms Bindoo Gupta	
Daulat Ram College Maurice Nagar New Delhi – 110 002	Dr Renu Saxena Ms Radha Saxena Mr Mohan Singh	Ms Anuradha Ms Priyanka Bansal Mr Prem Begani Ms Bani Bhattacharya Ms Sanjukta Ganguly Ms Sandeepa Gautam Mr Amit Kapatia Ms Ravinder Kaur Ms Chetna Laroiya Ms Anita Rani Ms Shweta Saran Mr Kulwant Singh Ms Shally Tomar Ms Rupali Walia
DAV Public School Tilak Nagar New Delhi – 110 018	Ms Renuka Kaul	Ms Atri Sujata Ms Geeta Grover
Delhi Public School Vasant Kunj New Delhi – 110 057	Ms Jaskiran Kaur Ms Malini Suri	Mr Debaskee Banerjee Mr Mohit Kumar Ms Ashima Makol Mr Akshay Sharma
Delhi Public School Sector 12, R K Puram New Delhi – 110 022	Ms Mita Brahma	Ms Kapadeep Chatterjee Mr Gaurav Mathur

School	Teacher(s)	Students(s)
Delhi Public School Mathura Road New Delhi - 110 024	Mrs Arwin Kaul Dr R C Tewari	Mr Pankaj Nanda
Dr T B Cunha Govt High School Altinho, Panaji Goa - 403 001	Mr S D Jangam	Mr Rahul Sood Mr Bright Thomas
Govt Senior Secondary School Siahar, Ludhiana - 141 117 Punjab	Mr S B S Mehrok	Mr Manveer Singh Mr Satwant Singh
Kendriya Vidyalaya II Army Area Pathankot Punjab - 145 001	Mr T Murali Mr R P Sharma	Mr Saurabh Sharma Mr Harnam Singh
Laxman Public School Hauz Khas Enclave New Delhi - 110 016	Ms Nirupma Ranjan	Mr Manan Bibidal Mr Amit Dyuti
Mahatma Montessori Matriculation Higher Secondary School Gopalakrishnan Grounds K K Nagar Madurai - 625 020 Tamil Nadu	Mr P Kanan	Mr J M H Shah
Manava Bharati India International School Panchsheel Park (South) New Delhi - 110 017	Mr Pant	Ms Sangeeta Chaudhary Ms Neha Kapur
Mata Jai Kaur Public School Ashok Vihar Phase III Delhi - 110 052	Ms Anjali Singh	Ms Smita Gupta Ms Fauzia Zaidi
Mater Dei School Tilak Lane New Delhi - 110 001	Ms Kamna Gupta Ms Prem Khilani	Ms Preet Aggarwal Ms Suparna Chopra Ms Auritra Ghosh Ms Sakshi Singhania
Naval Public School Chanakyapuri New Delhi - 110 021	Ms Maria Mathai	Mr Nishant Khetan Mr Deepankar Malik Mr Yudhister Mr Gaurab Paliwal

School	Teacher(s)	Students(s)
Oxford Senior Secondary School E Block, Vikaspuri New Delhi - 110 018	Ms Sunita Bathla	Ms Nidhi Jindal Ms Mridul Sharma
PSG College of Technology Post Box 1611 Peelamedu Coimbatore - 641 004 Tamil Nadu		Mr Anish G Mathews
Shri Chhatrapati Shivaji Junior College Sagroli TQ Biloli Nanded Maharashtra - 431 731	Mr S S Parlikar	Mr R P Deshmukh Mr Ramgarhia
St Columba's School Ashok Place New Delhi - 110 001		Mr Amit Mr Apar Jindal Mr Abhinav Pragya Mr Mark Nazareth
St Mary's Senior Secondary School Ambika Vihar New Delhi - 110 087	Ms Santosh Tiwari	Ms Priyanka Chauhan Mr Siddharth Naweti


Luckily, they belong to a world
that has Shell in it.

A global company that gives energy to your life.
Working around the world in successful partnerships.

You can be sure of Shell

Shell

SHELL 70943

OIL PRODUCTS • EXPLORATION AND PRODUCTION • GAS • CHEMICALS

gistered office : SIPL, S-3, International Trade Tower, Nehru Place, New Delhi-110019, India. Tel : 91-11-6469842, Fax : 91-11-6472341